PB-225 362

SEWAGE SLUDGE DISPOSAL IN A SANITARY LANDFILL

VOLUME II. DESCRIPTION OF STUDY AND TECHNICAL DATA

OCEANSIDE, CALIFORNIA

1973

Distributed By:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET

1. Report No.
EPA/530/SW-61d

2.

3. PB 225 362

4. Title and Subtitle
Sewage sludge disposal in a sanitary landfill
Volume II description of study and technical data

5. Report Date
1973

6.

7. Author(s)
Ralph Stone and Company, Inc.

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Ralph Stone and Company, Inc.
10954 Santa Monica Boulevard
Oceanside, California 90025

10. Project/Task/Work Unit No.

11. XXXXX/Grant No.
S 801582

12. Sponsoring Organization Name and Address
U.S. Environmental Protection Agency
Office of Solid Waste Management Programs
Washington, D.C. 20460

13. Type of Report & Period Covered
Interim-1972

14.

15. Supplementary Notes

16. Abstracts

This two volume report describes the results of work conducted during the first two years (January 1971-December 1972) of a three-year demonstration grant study of the disposal of liquid sewage sludge and septic tank pumpings into solid waste at a sanitary landfill. Pilot plant lysimeters were used to investigate the effects of sewage and septic tank sludges on solid waste temperature, decomposition, leachate, settlement, insects, gases, and odors. Three large field lysimeters were monitored for leachate, temperature, gas, compaction, settlement, and waste decomposition (as determined by core sampling). The full-scale disposal of sludge was monitored for runoff, leachate, equipment operating efficiency (time and motion studies), odors, vectors, blowing litter, and weather conditions (rainfall, temperature, wind, and evaporation).

17. Key Words and Document Analysis. **17a.** Descriptors

Waste disposal, urban areas, leaching, differential settlement, sewage disposal, sanitary engineering, water pollution, sewage treatment, effluents, septic tanks, sludge disposal, spreaders

17b. Identifiers/Open-Ended Terms

Solid waste disposal, sanitary landfill, Oceanside, California

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

17c. COSATI Field/Group 13B

18. Availability Statement

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page
UNCLASSIFIED

21. No. of Pages
376 382

22. Price
8.50/1.45

FORM NTIS-35 (REV. 3-72)

USCOMM-DC 14952-P72

339102

This report has been reviewed by the U.S. Environmental Protection Agency and approved for publication, Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of commercial products constitute endorsement or recommendation for use by the U.S. Government.

An environmental protection publication (SW-61d)
in the solid waste management series

ACKNOWLEDGMENTS

The City of Oceanside demonstration work reported herein was performed under Environmental Protection Agency Grant No. S801582 (formerly 1 G06-EC-00285-01A1) from the Office of Solid Waste Management Programs. The Year 01 work was conducted under the direction of Mr. Kent Anderson, former Project Officer; Mr. Leonard Lion, Project Officer, is reviewing the Year 02 and 03 work.

The Demonstration Grant was awarded to the City of Oceanside, California; Mr. Alton Ruden, Director of Public Works, serves as the Project Director and provided guidance necessary for the successful completion of this program. Mr. Richard Aldrich, Superintendent, Water and Sewage Department, Messrs. James Reed and John Calzada, Superintendent, and Assistant Superintendent, respectively, Waste Disposal Department, provided continuing assistance in performing the field work and collecting appropriate demonstration information.

Ralph Stone and Company, Inc. are the project consultants responsible for the detailed studies described in the report. Staff personnel include: Ralph Stone, Technical Supervisor; Richard Kahle, Project Coordinator; James Rowlands, Field Engineer, as well as many other Company professionals.

Valuable assistance in vector control and fly emergence studies was provided by the following agencies and individuals: State of California Department of Public Health, Bureau of Vector Control and Solid Waste Management - Mr. Harvey Magy, Southern California Area Representative; Dr. John Poorbaugh, Jr., Ph. D., Vector Ecologist and Mr. Don Andres, Senior Sanitary Engineer; San Diego County Department of Public Health - Mr. Daniel Bergman, Vector Ecologist. Mr. Dennis O'Leary, Executive Officer, San Diego Region, State Water Quality Control Board, cooperated in authorizing the leachate and groundwater quality tests. Many other Federal, State, County, local and private agencies and individuals have provided information to the program.

ABSTRACT

This two-volume report describes the results of two years' work (January 1971–December 1972) of a three-year demonstration study of the disposal of liquid sewage sludge and septic tank pumpings into solid waste at a sanitary landfill. Basic laboratory studies were conducted to determine the moisture absorbing capacity of typical solid waste constituents and to establish the leaching and other characteristics with various sludges. The composition and quantity of solid waste produced in the City of Oceanside were determined by first year quarterly waste samplings and waste collection vehicle weighings.

Pilot plant lysimeters were employed to investigate the effects of sewage and septic tank sludges on solid waste temperature, decomposition, leachate, settlement, insects, odor and gas characteristics. Three large field lysimeters were built at the City of Oceanside, California, municipal landfill, each holding one week's production of all municipal solid waste and sewage sludge. The field test cells were lined with a 10-mil polyethylene membrane to collect the leachate for measuring and sampling. Full scale demonstration landfill operations studies were conducted at the City landfills – initially with limited sludge disposal one day per week during Year 01, and with 100 percent sludge disposal during Years 02 and 03.

The large field lysimeters were monitored for leachate, temperature, gas, compaction, settlement and waste decomposition (as determined by core sampling). The full scale landfill disposal of sludge was monitored for runoff, leachate, equipment operating efficiency (time and motion studies), odor, vector problems, blowing litter, and weather conditions (rainfall, temperature, wind and evaporation).

Volume I consists of a 22-page summary, conclusions, and recommendations. Volume II is a 376-page description of the study on the sanitary landfill operating and design factors for disposing digested sludge and its effects on the sanitary landfill and environment. The demonstration study was supported in part by the U.S. Environmental Protection Agency under Grand Number S801582.

I. INTRODUCTION

A. Objectives and Scope of the Investigation

A three-year investigation of the economic and environmental effects of disposing of liquid sewage sludge and septic tank pumpings into a sanitary landfill is in progress. This report presents and discusses the results of the second phase (24 months) of the investigation. The objectives which are to be achieved during the study consist of the following:

1. Determine the capacity of solid waste to assimilate the water in digested liquid sludge and septic tank pumpings.
2. Identify the parameters affecting the capacity of solid waste to absorb water from liquid sludge and septic tank pumpings.
3. Determine optimum means for nuisance-free admixture of liquid sewage sludge with solid waste in a sanitary landfill.
4. Investigate and monitor sanitary landfill environmental effects following combined liquid sludge-solid waste disposal, i.e., temperature, odor, gas composition, settlement, flies, birds, other vectors, landfill leachate, groundwater contamination, and runoff.
5. Define the landfill effects of liquid sludge on solid waste compaction, decomposition rates, blowing dust and paper.
6. Determine effects of liquid sludge application on operating efficiencies of landfill equipment and personnel.
7. Investigate alternative means for dewatering, handling, and disposal of liquid sludge and establish cost comparisons.

The three-year demonstration program consists of the following areas of effort: a) establishing the water absorption characteristics of Oceanside sewage sludge and solid waste, b) pilot-scale landfill simulation experiments, c) large-scale field experiments under controlled conditions (field test cells), d) full-scale field demonstration, and e) special laboratory and/or field studies to eliminate or define sanitary landfill requirements. The work on the laboratory evaluation of water absorption by solid waste has been completed. The work on other tasks was initiated during the first year and is currently in progress. Three special studies which have been undertaken and completed are: a) laboratory evaluation of water absorption by solid waste, b) two nationwide postal surveys of landfill disposal of municipal sewage and septic tank sludges, and c) a literature search concerning digested sewage sludge and septic tank pathogens and vectors.

All the solid waste and sewage sludge used in the field demonstration study were obtained from the City of Oceanside. The full-scale Oceanside field demonstration disposed of the City's entire generation of liquid digested sludge into the solid waste at the City landfill.

B. Study Area Description

1. The City of Oceanside. The City of Oceanside, California is located within Northern San Diego County, as illustrated in Figure I-1. The City of Oceanside had a population of 40,494 in 1970. The City Planning Department has projected a 1980 population of 75,000, and a year 2000 population of 109,000. The year 2000 population is the maximum level for Oceanside in accordance with the proposed land uses. Residential density averaged 2.98 persons per household in the 1970 census. Of the total of 14,594 housing units, 9,139 were single dwelling residences, 4,307 were multi-unit residences, and 1,111 were mobile homes or trailers. Camp Pendleton, a major United States Marine Corps Base supporting about 35,000 Marine and Navy personnel, is located along the northern boundary of the City. Many of the Camp Pendleton personnel shop and visit in Oceanside.

The major land use categories in the City limits are given in Table I-1. The average residential zoning density was about 19 persons per acre in 1970.

Selected Oceanside climatological data for 1971 and part of 1972 are given in Table 1-2. The U. S. Weather station at the nearby Palomar Airport reports a mean 112-year historical precipitation average of about 12 inches.

2. Sewage Treatment Plants. The City of Oceanside has three existing sewage treatment plants; two are activated sludge plants named La Salina and Buena Vista. A third is a primary type plant named San Luis Rey. Detailed description of these sewage plants and a discussion of the quantity, and characteristics of the sludge produced in each plant are presented in Chapter IV. The plant sites are shown in Figure 1-2.

3. Sanitary Landfills. During the first year of the study, all preliminary demonstration field tests were made at the old City sanitary landfill (see Figure 1-2) located southerly of Mission Avenue and easterly of the San Diego Freeway (Interstate 5). The old site was completely filled and a new City sanitary fill site was prepared including 3 test cells for the second and third year demonstration work. The new site, shown in Figure 1-2,is in a canyon located northerly of Mission Avenue and easterly of Cape Glouchester Street. A Marine Corps housing project and primary and elementary schools are the neighbors on the canyon rim abutting the new site. The Oceanside landfill receives primarily commercial and residential waste from within the City. As will be discussed in detail in Chapter IV, relatively little industrial waste is received at the new landfill. The local soils are coarse to fine sand over well-consolidated sandstone. Geology, soil and groundwater conditions are described in Appendix G. Prior to September 9, 1972, the Oceanside landfill did not receive daily cover soil on the working face. In order to comply with EPA sanitary landfill requirements, a six-inch minimum compacted cover soil was applied daily to the landfill working face after September 9, 1972.

TABLE I-1

MAJOR CLASSES OF LAND USE IN OCEANSIDE--NOVEMBER 1967

Land use	Acres	Percentage of Total city	 Developed area
Residential	2,131.70	10	38
Industrial	465.54	3	8
Commercial	461.23	3	8
Highways--streets	1,607.84	7	28
Public & semi-public	1,050.10	5	18
Subtotal Developed area	5,716.41	28	100
Agriculture	3,447.13	15	
Vacant	12,660.58	57	
Total area	21,824.12	100	

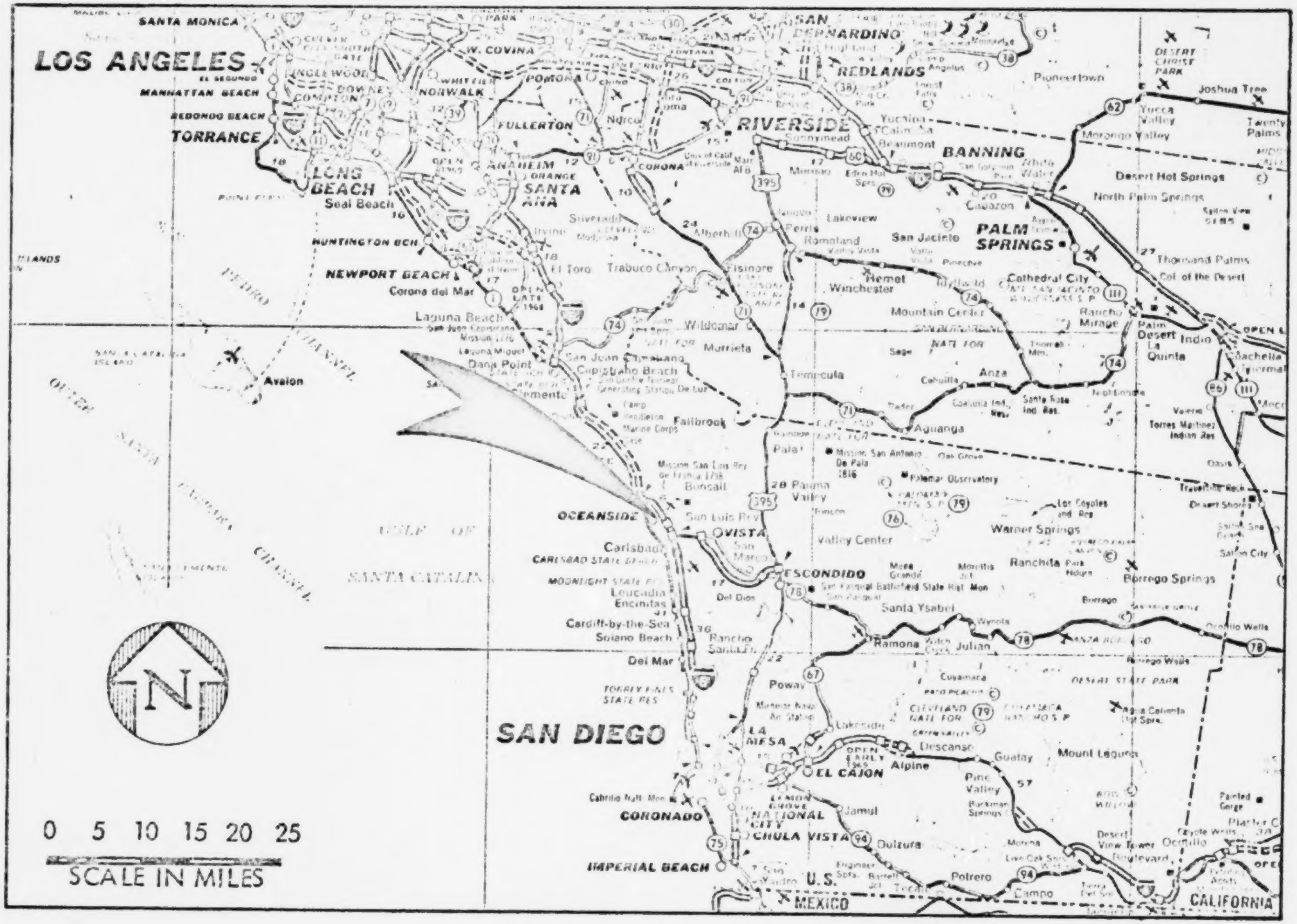
From: Oceanside Planning Department

TABLE 1-2

OCEANSIDE CLIMATOLOGICAL DATA

	Temperature (F)				Precipitation (in.)	
Month	Avg max	Avg min	Avg	High/low	Total	24 hr max
1971						
Jan	64	43	57	78/30	0.39	0.36
Feb	64	44	58	81/35	1.34	0.68
Mar	64	47	59	74/34	0.10	0.10
Apr	69	49	62	84/42	0.89	0.66
May	66	51	63	78/48	0.69	0.32
June	71	58	68	78/49	0	0
Jul	76	61	71	80/46	0	0
Aug	82	66	77	86/60	0	0
Sept	78	61	73	85/80	0	0
Oct	74	52	69	98/36	0.67	0.47
Nov	66	46	59	75/41	0.13	0.8
Dec	61	41	54	69/34	3.37	0.81
		1971 Total precipitation --			7.58	
1972						
Jan	62	41	55	80/35	0	0
Feb	64	41	57	71/37	0.11	0.11
Mar	65	50	59	73/41	0	0
Apr	68	49	63	72/40	0.05	0.03
May	70	54	66	76/47	0.16	0.10
June	73	60	69	77/54	0.20	0.11
July	78	62	73	83/51	0	0
Aug	79	63	75	87/49	0.03	0.3

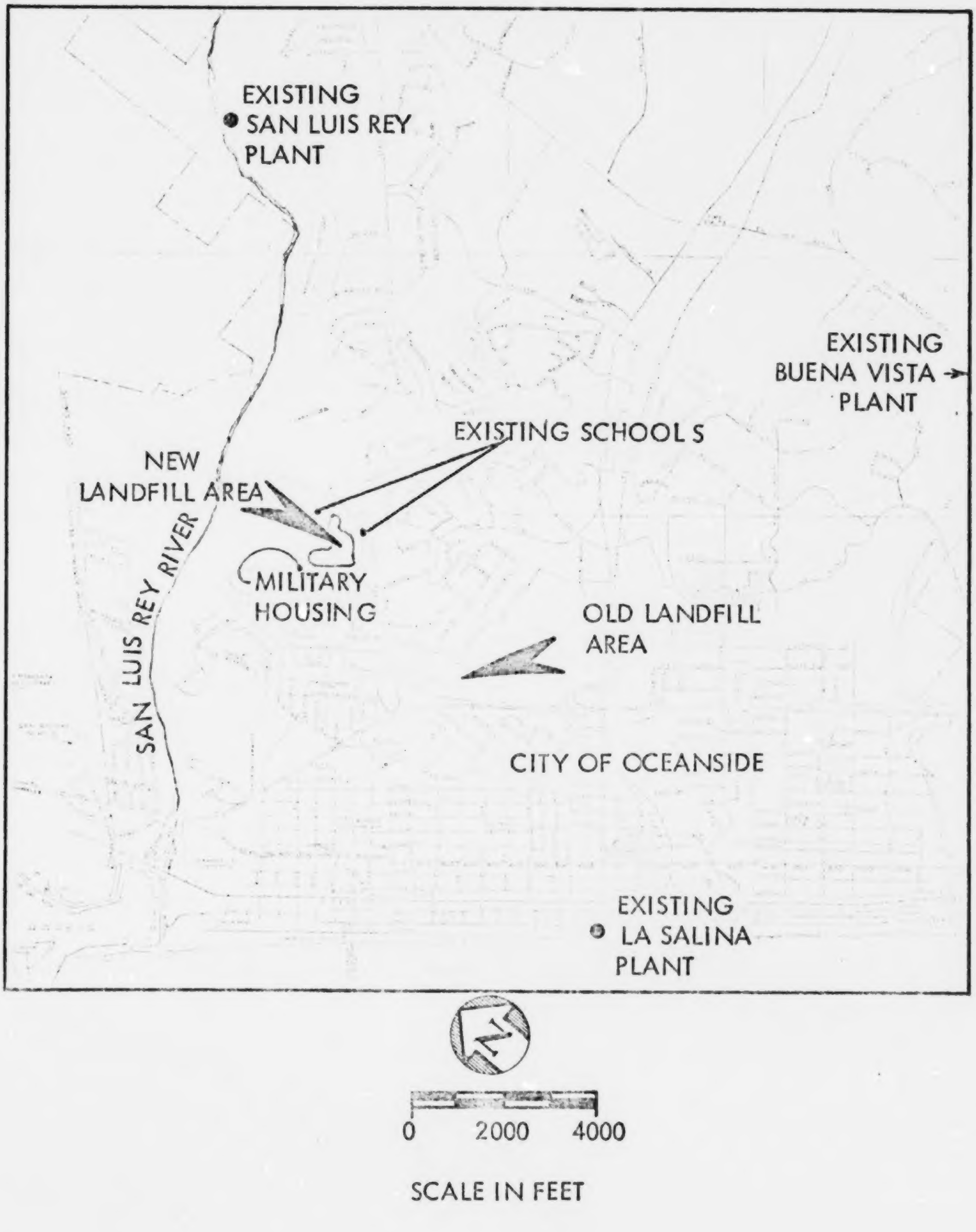
From: Oceanside fire station


LOS ANGELES
SANTA MONICA
MANHATTAN BEACH
REDONDO BEACH
TORRANCE
LONG BEACH
Seal Beach
HUNTINGTON BCH
NEWPORT BEACH
Corona del Mar
Laguna Beach
Dana Point
W. COVINA
WHITTIER
NORWALK
POMONA
FULLERTON
ANAHEIM
ORANGE
SANTA ANA
CORONA
Norco
SAN BERNARDINO
REDLANDS
RIVERSIDE
BANNING
PALM SPRINGS
Cathedral City
Rancho Mirage
Palm Desert
Indio
La Quinta
Desert Hot Springs
North Palm Springs
Thousand Palms
Pioneertown
Yucca Valley
Joshua Tree
Twentynine Palms
Hemet
San Jacinto
Perris
Lakeview
Romoland
Winchester
Elsinore
Wildomar
Murrieta
Temecula
Aguanga
Anza
Mountain Center
El Toro
Trabuco Canyon
San Juan Capistrano
Capistrano Beach
Fallbrook
Pala
Pauma Valley
Bonsall
OCEANSIDE
VISTA
San Marcos
Carlsbad
Leucadia
Encinitas
Cardiff-by-the-Sea
Solano Beach
Del Mar
Rancho Santa Fe
ESCONDIDO
Valley Center
Warner Springs
Santa Ysabel
Ramona
Julian
Poway
SAN DIEGO
LA MESA
EL CAJON
Lakeside
Alpine
Descanso
Guatay
Pine Valley
Mount Laguna
Borrego Springs
Ocotillo Wells
NATIONAL CITY
CHULA VISTA
CORONADO
IMPERIAL BEACH
Jamul
Dulzura
Potrero
Campo
U.S.
MEXICO
CALIFORNIA
Avalon
GULF OF SANTA CATALINA
N
0 5 10 15 20 25
SCALE IN MILES

CITY OF OCEANSIDE/E.P.A.

FIGURE I-1

STUDY AREA LOCATION


EXISTING SAN LUIS REY PLANT
EXISTING BUENA VISTA PLANT
EXISTING SCHOOLS
NEW LANDFILL AREA
SAN LUIS REY RIVER
MILITARY HOUSING
OLD LANDFILL AREA
CITY OF OCEANSIDE
EXISTING LA SALINA PLANT
N
0
2000
4000
SCALE IN FEET

CITY OF OCEANSIDE/E.P.A.

FIGURE I - 2
OCEANSIDE MUNICIPAL
LANDFILL SITE

II. SLUDGE DISPOSAL PRACTICES

A. General Aspects of Sludge Disposal in the United States

Currently, sludge processing, handling and disposal represent about 25 to 50 percent of the total capital and operating cost of municipal sewage treatment plants. Sludge disposal involves the ultimate complex phase of wastewater treatment and plant management. While sewage sludge has some limited fuel and soil conditioning value, it is generally a liability at treatment plants due to a lack of markets for these latter uses. Commercial chemical fertilizers are less expensive to handle; they do not present potential environmental problems from odors or public health hazards from pathogenic organisms and vectors associated with poorly digested sewage sludges.

A number of sludge treatment and disposal methods are utilized which include: anaerobic and aerobic digestion, composting, drying, wet burning, chlorination, incineration, landfilling or burial, reclamation as a soil conditioner, lagooning, deep well injuection and discharge to water bodies. A study completed in 1968 by Burd[1] summarized the costs for alternative handling and disposal methods for municipal sewage sludge. These costs are given in Tables II-1 and II-2. Lagooning and landfilling were indicated as the least costly handling and processing methods (Table II-1). As a means for ultimate disposal, landfilling with dewatered sludge is more costly than lagooning, barging to sea, and pipeline to sea (Table II-2). In many cases, ultimate sludge disposal requires pretreatment for dewatering. The cost of dewatering often accounts for a significant fraction of the total disposal cost.

The Marine Protection and Sanctuaries Act of 1972(PL 92-532) sets strict requirements on the ocean disposal of sewage sludge; the Federal Water Quality Act (PL 92-500) as amended in 1972, sets strict requirements on pipeline discharges into the ocean. These regulations may eventually force many municipalities to seek alternative methods for sludge processing and disposal. The need for environmentally desirable and economic methods of sludge processing and disposal is particularly acute in some urban areas where current methods are unacceptable (e.g., elimination of sludge burning due to air pollution, or removal of sludge discharges from receiving waters and prohibitively high costs of sludge handling due to the unavailability of suitable nearby disposal sites). One method of sludge disposal which has received some attention in recent years and which appears to be of considerable promise is the admixture of liquid digested sludges to solid waste in a landfill. As will be discussed later, certain advantages are inherent in this combination approach to the solution of sludge and refuse disposal problems, which may make the method very appealing to some communities.

B. Nationwide Surveys of Sludge Disposal to Landfills

In 1971, Ralph Stone and Company, Inc. independently undertook a nationwide survey of State Public Health Departments and local landfill managers to assess the prevalence of sludge disposal to landfills and explore any problem(s) which may be associated with this method of sludge disposal. Copies of the questionnaires are included in Appendix B.

TABLE II-1

SLUDGE HANDLING AND PROCESSING COSTS (1968)*

System	Capital and operating costs ($/dry ton) Average	Range
A. Thickening		
(1) gravity	-	1.50 - 5
(2) air flotation[+]	-	6 -15
(3) centrifugation[+]	-	3 -20
B. Dewatering		
(1) vacuum filtration	15	8 -50
(2) centrifugation	12	5 -35
(3) sand bed drying	-	3 -20
C. Anaerobic digestion	-	4 -18
D. Elutriation	-	2 - 5
E. Lagooning	2	1 - 5
F. Landfilling	-	1 - 5[#]
G. Pipeline transportation	5	**
H. Liquid sludge disposal on land as a soil conditioner	10	4 -30
I. Heat drying	35	25 -40
J. Incineration	20	8 -40
K. Barging to sea	10	4 -25

* From: Burd, R.S. A study of sludge handling and disposal. FWPCA Publication No. WP-20-4, 1968, p. 320

[+] Varies tremendously depending on the need for chemicals.

[#] Long hauls would be higher.

** Moderate distances, cost varies with length.

TABLE II-2

ULTIMATE DISPOSAL COSTS FOR SEWAGE SLUDGE (1968)*

System	Capital and operating costs[+] ($/dry ton) Average	Range
A. Composting	Not accurately known	
B. Heat drying[#]	50	40-55
C. Incineration		
(1) wet combustion	42	-
(2) multiple hearth and fluidized bed	30	10-50
D. Landfilling dewatered sludge	25	10-50
E. Disposal as a soil conditioner w/o heat drying (dewatered)	25	10-50
F. Disposal on land as a liquid soil conditioner	15	8-50
G. Lagooning	12	6-25
H. Barging to sea	12	5-25
I. Underground disposal	Unknown, potentially inexpensive	
J. Pipeline to sea	11	-

---

[*] From: Burd, R.S. A study of sludge handling and disposal. FWPCA Publication No. WP-20-4, 1968, p. 320.

[+] Includes cost of preparation, such as dewatering, digestion, etc. given in Table II -1.

[#] Gross cost, does not account for money received from sale of sludge.

1. Health Departments Survey. The questionnaire (see Appendix) was designed to survey prevailing nationwide practice and opinion concerning sewage sludge and septic tank sludge landfill disposal. The sanitary engineers/environmental health officers in the 50 State Departments of Public Health were sent questionnaires. A total of 26 states responded; 24 provided answers to all or most questions. The following is a summary of the survey results.

a. Sludge Disposal Regulations. Landfill disposal of sewage and/or septic-tank sludge was permitted by 80 percent of reporting states. The responses for municipal sewage sludge were: permitted, 16; prohibited, 4; and for septic tank sludge: permitted, 17; prohibited, 4. Most of the states had the same disposal policy for both types of sludge. One state, however, restricted landfill sludge disposal to municipal sludge only, and two states limited such disposal to septic tank sludge.

Regulation of landfill disposal of municipal sewage sludge was reported by 10 states; of septic tank sludge, by 11 states. State inspection was reported by six states; two of these prohibited all sludge disposal, three permitted both municipal and septic tank sludge disposal, and one of the inspecting states permitted only septic tank sludge disposal. Several states indicated that municipal sewage sludge accepted for landfill disposal had to be dried and/or dewatered.

b. Problems Associated with Landfill Disposal. Most of the states which permitted municipal-sewage and/or septic-tank sludge disposal to landfill also permitted landfill disposal of industrial, other liquid, and/or hazardous wastes. It was, therefore, not always possible to determine which type of sludge was responsible for associated environmental difficulties. The following list of comments on adverse sludge-related problems was compiled:

High water content of sludge makes landfilling almost impossible.
Adverse public opinion, damage to equipment.
Increased potential leachate problem.
Excessive leachate production, inefficient and sloppy operation, flash fires, probable ground water pollution (being investigated on one site).
Increased probability of spread of disease by vectors.
Creation of a nuisance because of disposal in an unsafe manner and in unregulated places.
Odor problems when regulations not complied with.
Difficulty in compacting liquid wastes prior to daily cover.
Difficulty in burying sewage (vacuum filtered) sludge. (Improved mixing with solid waste not a problem.)

Four states reported no known problems to date; two states indicated a lack of information; and the remainder either failed to respond to the question, or specified the problems were caused by other types of liquid/hazardous wastes.

c. Recommended or Existing Alternatives to Landfill Disposal. Incineration, treatment, and recycling (especially as fertilizer by direct land application) were the most commonly listed alternatives to landfill disposal of municipal-sewage/septic-tank sludge. The following are respondents' comments concerning recommended or existing alternatives:

Incinerate sludge; provide tertiary treatment of the liquid from sludge dewatering.
Incineration and pretreatment prior to discharge.
Incineration, recycling, or recovery.
Incineration, higher degree of neutralization or chemical treatment.
Combustion where applicable.
Recycling, incineration conversion to solids.
Better treatment plants; recycling or finding new uses for the wastes.
Treatment when available, sludge drying and land disposal, special burial areas.
Anaerobic or aerobic digestion or treatment.
Dispose liquid or dry digested sludge on flat farm land, and plow under.
Dispose of municipal sewage sludge on farm land.
Drying bed, then use as fertilizer (sewage sludge from municipal plants).
Ground sludge used for municipal parks, septic tank wastes discharged to central sewage treatment plants.
Land spreading, lagooning, incineration, or "purifying".
Deposit in slit trench and allow moisture to leach away into soil. Cover periodically.
Sand drying beds or lagoons.
Lagoons.
Written permission now required; cease and desist orders on existing sites with problems; no approval for sites with leachate or potential groundwater problems.
Methods should be according to conditions.

d. Environmental Impact. Respondents were asked to evaluate on a scale of 0 (none) to 10 (very great) the severity of hazards and problems anticipated from landfill disposal of sewage sludge. Table II-3 summarizes the information.

The median and the mode are values indicating central tendency. The median is the middle value, or that rating value which divides the ranked data into two equal parts. The mode is the value of greatest frequency, or that rating value which received the largest number of responses. The medians were: municipal sewage sludge, 3; septic tank sludge, 4--indicating respective clusters of consensus at the very little and very moderate levels of anticipated environmental hazard. The modes were 1 (6 out of 24 responses) for sewage sludge and 4 (7 out of 24 responses) for septic tank pumpings.

In the no-to-little hazard categories (0 through 3), the number of responses were: municipal sewage sludge, 13; septic tank sludge, 7. Responses in the moderate

TABLE II-3
ANTICIPATED LEVEL OF ENVIRONMENTAL HAZARDS AND PROBLEMS ASSOCIATED WITH LANDFILL DISPOSAL OF MUNICIPAL SEWAGE/SEPTIC TANK SLUDGE

(Scale of 0 to 10; 0 = none, 10 = great hazard)

	Rating level of hazards/problems by number of responses														
	None	Little				Moderate					Great				
Type of sewage	0	1	2	3	Sub-total	4	5	6	7	Sub-total	8	9	10	Sub-total	Total
Municipal sewage	1	6	2	4	13	1	5	0	4-1/2*	10-1/2	1/2*	0	0	1/2	24
Septic tank	0	2	3	2	7	7	4	2	2-1/2*	15-1/2	1-1/2*	0	0	1-1/2	24

*Two respondents gave range of 7-8

rating range (4 through 7) reversed these proportions: municipal sewage sludge, 10 1/2 responses; septic tank sludge, 15 1/2. The only responses in the category of great anticipated hazard (8 through 10) were municipal sewage sludge, 1/2; and septic tank sludge, 1 1/2. (Fractions result from two 7-8 rating responses.)

In general, therefore, the responding state department of health officials anticipated only little or moderate environmental hazard as the result of landfill disposal of either type of sludge; more serious difficulties, however, were expected for septic tank than for municipal sewage sludge.

2. Detailed Description of Survey of Landfill Managers. The postal questionnaire (see Appendix) was designed to survey prevailing practices and opinions concerning the disposal to sanitary landfills of sewage and septic-tank sludge. The questionnaire was distributed nationwide to the City Engineers or Directors of Public Works of 475 cities with minimum populations of 10,000 (19.2 percent coverage). A total of 174 cities and two counties responded; of these, 44 had no operating landfills under their direct jurisdiction. The questionnaires were, therefore, answered, in whole or in part, by officials of 132 jurisdictions. Incomplete responses are responsible for the wide variations in totals which, for any one question, were usually below the possible maximum.

a. Landfill Sludge Disposal. The majority of 122 landfills reporting on whether sludge disposal was permitted did not permit disposal of any sludge (sewage/septic tank/industrial, liquid, or hazardous wastes). The responses were: disposal permitted, 36 (30 percent); prohibited, 86 (70 percent). Twenty-nine of the landfills which permitted sludge disposal identified the waste as sewage and/or septic tank sludge: sewage sludge only, 19; septic tank sludge only, 3; sewage and septic tank sludge, 7.

b. Service Population. The service population distribution for the 29 cities permitting sewage/septic tank landfill sludge disposal was:

Population			Number of Cities
10,000	-	50,000	11
50,001	-	100,000	7
100,001	-	500,000	8
more than		500,000	3
Total		4,622,000	29

c. Distance from Nearest Residential Area. Of 27 reporting sewage/septic tank disposal landfills, 25 were 1/4 mile or more from the nearest residential area. The most commonly identified distance was 1/2 mile (nine landfills). The two landfills in close proximity to residential areas were about 200 ft from the nearest housing.

d. Public Versus Private Operation. Of a total of 118 responding landfills, 99 (85 percent) were public, and the remaining 19 (15 percent) were private operations. Of the 29 landfills permitting sewage/septic tank sludge disposal, 23 (79 percent) were public, 5 (17 percent) were private, and 1 (4 percent) was unidentified.

e. Future Landfill Use. The 28 responses received concerning the future land use of the landfills accepting sewage/septic tank sludge were: park/recreation/golf course/landscaping, 15; agriculture, 5 (farm/crops, 3, and grazing, 2); agriculture or recreation, 1; storage area for digested sludge to be used as soil conditioner, 1; return to landowner, 1; not known, 4; and no future use planned, 1.

f. Type of Landfill Operation. The distribution of responses received from the 29 landfills permitting sewage/septic tank sludge disposal was: cut and cover, 13; canyon or ravine, 5; pit or quarry, 3; unidentified, 2; and the remaining 6 were variously described as sludge harvest, diked flood plain area, spread and dry, diked in marshland, trench, and area fill. One of the cut and cover operations was identified as an old strip mine.

g. Size of Landfill. Most of the 18 sites reporting sewage/septic tank sludge disposal into landfills were 100 acres or less in area. The area size distribution was:

Acres	No. of Landfills
less than 50	8
51 - 100	4
101 - 150	0
151 - 200	5
more than 2,500	1
Total	18

For 21 landfills reporting sewage/septic tank sludge disposal, the distribution of final depth of fill was:

Final Depth (ft)	No. of Landfills
less than 10	5
11 - 20	7
21 - 30	5
50 - 100	4
Total	21

h. Quantities of Sewage/Septic Tank Sludge Disposed. Septic tank pumpings represented less than one-half of one percent of the total sewage sludge disposed at reporting landfills. Table II-4 summarizes the data.

i. Sludge Disposal Methods. The following are the responses to the inquiry concerning the methods of applying sewage/septic tank sludge at landfills:

Dumped in sand and gravel within open pits previously dug by bulldozer; pits then filled to control odor and other problems.

TABLE II-4

ESTIMATED QUANTITIES OF SEWAGE AND SEPTIC TANK SLUDGE DISPOSED AT REPORTING LANDFILLS

Type of sludge	Quantity disposed				Sludge solids content		
	No. of reporting landfills*	Total annual quantity		Avg. annual quantity per landfill	No. of reporting landfills*	Range	Median
		1000 gal/yr	Percent	1000 gal/yr		Percent dry weight	
Municipal sewage	16	534,945	99.6	33,434	24	0.5-97[+]	8
Septic tank	8	2,461	0.4	308	7	2-85[+]	10
Total		537,406	100.0				

* Some landfills allow both municipal and septic tank sludges.

[+] Probably contains appreciable amounts of sand and other inert solids.

Note: Liquid sludge solids are generally in the range of 1.5 to 6 percent dry weight. Dried sludge, of course, has far less water.

Dumped at site and leveled.
Dumped on top of fill and mixed with refuse during compaction.
Dumped into pit.
Dewatered by vacuum filtration: moved to landfill, dumped, and immediately buried.
Only air-dried digested sludge accepted.
City landfill disposal of sludge unregulated.
All sludges incinerated (ashes disposed to landfill, presumably).
Six-percent solids sludge pumped to area, liquid discharged daily to sloped drying beds; separated clear supernatant decanted to sewer system; and remaining solids drained, dried, and harvested for park fertilizer use.
Spread and tilled into the soil.
Spread on field where no other waste allowed; tilled and mixed with field dirt.
Allowed to air-dry, then shredded and used for lawn fertilizer.

j. Environmental Protection. Table II-5 summarizes the responses to key questions related to the existing environmental protection procedures (use of daily refuse cover, compaction, etc.) at landfills which accept municipal sewage sludge and septic tank pumpings.

k. Anticipated Hazards and Problems. All respondents, irrespective of local sewage-sludge disposal practice, were asked to evaluate on a scale of 0 (none) to 10 (very great), the potential severity of hazards and problems which might result from landfill disposal of sewage and septic tank sludge. The data is summarized in Table II-6.

The median ratings for municipal sewage sludge and septic tank sludge were 2 and 5, respectively. This indicates that the respondents believed that the municipal sewage sludge (presumably well digested) is considerably less hazardous than septic tank sludge. The modal values were zero (22 out of 99 responses) and 8 (13 out of 92 responses) for the municipal sewage sludge and septic tank sludge, respectively. There was a considerable divergence of opinion on hazards of septic tank sludge; rating values ranging from zero to 10 were reported by 12 of the respondents. The results thus indicated that septic tank pumpings were considered potentially more hazardous than municipal sewage sludge.

l. Special Comments. Practical experience with septic tank pumpings has demonstrated that they are both odoriferous and contain pathogenic type microorganisms.[4] Nevertheless, the septic tank pumpings may be satisfactorily disposed within sanitary landfills if special precautions are taken to assure proper spreading, absorption into solid waste, soil cover, leachate control and sanitation. Good sanitation practices would include isolation of operating personnel and vectors from contact with the pumpings. Isolation of personnel may require restricting their access to areas where septic tank pumpings are disposed (except for equipment operators),

TABLE II-5

ENVIRONMENTAL PROTECTION PROCEDURES AT LANDFILLS ACCEPTING SEWAGE/SEPTIC TANK SLUDGE

Questions Do procedures exist for:	No. of responses Yes	No	Responses Description/Comments
Catching drainage from sludge overflow?	13	12	Reservoirs; no overflow; mix sludge with refuse; dikes and decant beds.
Isolating landfill from contact with groundwater?	14	12	Compact base prior to filling; trenches lined with clay: clay liner is used; contained inside diked area; pumped; lagooned: seepage to bay.
Isolating landfill from surface drainage?	15	10*	Storm sewer system around the site; bury before contact: berms; dikes and levees: diked; lagooned; landfill not located in natural drainage channel; little surface drainage; only rainfall enters.
Daily cover of refuse?	22	5	
Compaction?	12	10	

*One reporting landfill plans to establish procedure in the future.

TABLE II-6
OPINION RATINGS OF ANTICIPATED PROBLEMS/HAZARDS ASSOCIATED WITH LANDFILL DISPOSAL OF SEWAGE AND SEPTIC TANK SLUDGE

(scale of 0 to 10; 0 = no hazard, 10 = very great hazard)

	Problem/hazard rating value responses in percent					
Type of waste	None 0	Little 1-3	Moderate 4-7	Great 8-10	Mean	Mode
Municipal digested sewage sludge	22	39	26	12	2	0*
Septic tank pumpings	12	21	38	28	5	8+

* Of 99 responses, 22 were at zero.

+ Of 92 responses, 13 were at eight.

wearing face masks and protective clothing. Effective operating supervision is needed to assure prompt soil cover of the fill, thereby eliminating odor nuisance, protecting against pathogens and restricting vectors.

The Great Britain Royal Commission on Environmental Pollution presented two reports to Parliament in February 1971 and March 1972 which identified wastes disposed into landfills in England that were considered "toxic". No mention of sewage sludge as being toxic or otherwise hazardous was made in either report.

3. 1962 Survey Comparison. A separate survey completed in 1962 by Ralph Stone for the ASCE[2] indicated that 19 percent of reporting landfill operators permitted the disposal of sewage and septic tank sludges. The lower rate of permitted disposal was given by respondents as resulting from disposal sites being located too near usable waters. The risk of contamination from leachate was considered too high for septic tank sludge disposal into many reporting landfills.

Comparing the results of the 1962 and 1971 Ralph Stone and Company, Inc., surveys, the percentage of respondents in 1971 that indicated landfill disposal of digested liquid sewage and septic tank sludges was permitted was 50 percent greater than the number respondents indicating such permission in the 1962 survey. This comparison assumes that the respondents in both surveys were equally representative of all landfill operations. The cause of any trend could result from increasingly more stringent water quality standards preventing disposal to water bodies and high costs of alternative sludge disposal methods. Also, many, if not most, of the landfills now probably receive some partially dried sludges. In regard to the high risk of water contamination, only about 50 percent of landfills permitting sewage sludge disposal in the 1971 survey had established procedures to catch drainage from sludge overflow and to isolate the leachate from ground water contact; 60 percent had procedures for isolating their landfill from surface drainage. Thus, while protection of receiving waters is of major problematic concern from a public health and water quality standpoint, operating practices do not appear to fully reflect this concern.

III. OCEANSIDE SOLID WASTE AND SEWAGE SLUDGE CHARACTERISTICS

A. Solid Waste Characteristics

In order to determine the feasibility of disposing all of the liquid digested sewage sludge generated in the City of Oceanside into the Oceanside landfill, a study was undertaken to establish the quantity, general make-up, organic content, and moisture percentage of the Oceanside solid waste. The description and the results of this study are presented below.

1. Sampling Methodology. The City's Waste Disposal Department collects once a week from single family and small apartment residential units, and two to three times per week from large apartment buildings, commercial and industrial sites. No private collectors operated in the City as of 1972. The collectors completed a special census to determine the number and type of collection stops during a one-week period in February 1971. The resulting information concerning the distribution of collection stops serviced each day of the week and the type of stops (residential, apartment, commercial/industrial) are given in Table III-1.

A one percent solid waste sample size based on the total number of stops collected per week was selected; based on a total of 12,430 stops, the one percent sample size (133 stops) should provide a statistical confidence level of 95 percent at about 9 percent precision (error). The stops used for sampling solid waste were selected using random number tables and then counting down the City Sewer Department billing list and recording the address each time a specified random number was reached. The number of stops for sampling were stratified by type of stop and day of the week as shown on Table III-1.

One waste collection truck operated by a two-man crew was accompanied by a member of the Consultant's staff to test-sample the solid waste. The vehicle preceded the regular collection trucks each day Monday through Friday once each seasonal quarter of the first year demonstration to obtain four separate representative solid waste samplings from the same randomly selected collection stops. All waste sample vehicles were weighed and then the samples were taken to the City's landfill for hand sorting into the standard nine major categories defined by the Environmental Protection Agency (EPA), Office of Solid Waste Management Programs (OSWMP).Several of the nine major categories were further broken down by sorting into sub-categories to separate wastes that absorb moisture from those that are non-absorbent as follows: paper--newsprint, cardboard, and miscellaneous paper; garden wastes--tree and shrub prunings, leaves ,and grass; plastic, rubber, and leather--foam materials and solid materials; dirt, ash and sand were differentiated from concrete and rock.

TABLE III-1

SOLID WASTE SAMPLING*

Feb. 1971 week	Collection stops (no.)				Sample stops (no.)			
Day	Res.	Apt.	Com. & indus.	Total	Res.	Apt.	Com. & indus.	Total
Mon	1,332	428	540	2,300	14	5	7	26
Tue	1,823	116	367	2,306	19	2	4	25
Wed	1,329	140	586	2,055	15	3	7	25
Thu	1,729	269	364	2,362	18	3	4	25
Fri	2,282	213	442	2,937	23	3	6	32
Sat	64	151	255	470	0	0	0	0
Totals	8,559	1,317	2,554	12,430	89	16	28	133

---

*Sample size is 1 percent of the total number of stops in the City of Oceanside, California.

In addition to sampling wastes quarterly, all of the waste collection vehicle loads collected during a one-week period each quarter of the first year demonstration were weighed prior to unloading at the landfill. One week each month the vehicles disposing to the City landfill were tabulated daily by type of vehicle and type of solid waste. A designated landfill equipment operator was trained to perform this latter categorization. The landfill vehicle tabulation data sheet is shown in Appendix B.

2. Waste Characteristics. The solid waste sampling procedure described in the preceding section yielded the results shown on Table III-2 for the four sampling periods of 1971. The percentages in the total column are based on the combined weights of each component for all four sampling periods.

Moisture analyses of the samples selected as representative of each component are given in Table III-3. It should be kept in mind that these analyses represent the moisture content of solid waste as received at the landfill site. During the April sampling period, one day of rainfall occurred. There was rainfall as the truck traversed the route collecting the sample for at least one day's sorting. This rainfall is probably reflected in the notably higher moisture content of papers, textiles, and foam plastics during the latter period than was found in the other three sampling periods.

The organic content of the various components is presented in Table III-4, and shows relatively little seasonal variation. Of possible significance may be the greater organic content of the dirt, ash and sand category in July (summer) which may be attributed to the greater grass cutting during the warm growing season. Methods used to determine moisture and organic content are described in Appendix A.

During 1971 the Boys' Club conducted a newspaper drive and the Girl Scouts sponsored an aluminum can salvage program. A comparison of the City of Oceanside solid waste composition with that of the City of Los Angeles in Table III-5 shows less newsprint, but more metals, for Oceanside. Apparently, the aluminum can salvage had little effect on metals content in the solid waste, but the newsprint salvage program which was highly publicized with special collection bins in shopping center parking lots significantly reduced its presence in the solid wastes. Other reported solid waste contents are also described in Table III-5 for comparison purposes.

During the first year, a portion of the old Oceanside municipal landfill was excavated as part of a construction project. Several samples of solid waste materials were obtained and analyzed from the excavation to a depth of 15 to 20 feet. The samples were analyzed for total solids and organic content. The results are shown in Table III-6. A comparison of the materials obtained from the excavation which were placed in January 1963 with those sampled in 1971 shows very little difference in organic content, thus indicating that the decomposition was negligible. The excavated magazines and newspapers were easily read, and tree, shrub, and grass leaves were still green. The sampled wastes exhibited negligible degradation after almost nine years of sanitary landfill burial. The opened landfill was extremely odoriferous and the old waste was quickly reburied and covered with earth.

TABLE III-2
COMPOSITION OF OCEANSIDE MUNICIPAL SOLID WASTE
(1971)

	Composition (percent dry weight)				
Category of waste	April	July	Oct.	Dec.	Weighted average*
Newspaper	6.1	4.9	8.6	10.3	7.2
Cardboard (corrugated & solid)	6.3	8.5	9.3	9.8	8.3
Miscellaneous paper	24.4	28.2	17.4	23.8	23.6
Total paper	36.8	41.6	35.2	43.9	39.1
Food waste	9.5	9.5	7.5	9.7	9.2
Glass & ceramics	15.5	9.9	12.1	15.5	13.3
Metals	8.3	8.4	9.6	9.4	8.8
Trees & shrub prunings	9.7	6.3	4.8	3.1	6.3
Leaves					
Grass	2.0	7.9	1.8	1.7	3.8
Total garden waste	11.7	14.2	6.6	4.8	10.1
Textiles	1.9	2.7	2.6	2.1	2.3
Total Rubber, Plastics and Leather	7.9	2.7	5.7	4.4	5.3
Wood	1.9	1.8	2.9	1.8	2.1
Dirt, ash, & sand	0.5	0.3	0.8	0.4	0.5
Concrete & rock	0.1	1.3	0.4	Neg	0.4
Other (unclassifiable)	5.9	5.6+	16.5+	8.0+	8.9
Grease	0	0.4	0	0	
Total	100.0	100.0	100.0	100.0	100.0

*Obtained by summing the weight of quarterly samples for each category of waste, and then calculating the weighted average based on the total 14.5 tons dry weight of all samples.

+ All material passing through 2-inch sieve.

TABLE III-3
MOISTURE CONTENT OF OCEANSIDE SOLID WASTE
(1971)

Category of waste	One week's average (percent dry weight) April	July	Oct.	Dec.	Weighted Average*
Garbage	58.1	79.7	73.2	72.8	70.9
Textiles	24.9	11.2	19.8	9.9	16.4
Grass	57.1	51.3	65.6	56.3	57.6
Wood	17.6	11.1	14.0	15.5	14.6
Newsprint	43.4	27.6	27.3	15.7	28.5
Cardboard	34.4	14.9	26.1	21.3	24.2
Misc. paper	35.6	17.9	21.6	17.4	23.1
Prunings, leaves	--	58.7	29.5	42.4	43.5
Foam plastic, rubber	51.9	4.6	17.8	--	24.8
Hard plastic, rubber and leather	9.4	4.9	--	10.4	8.2
Dirt, ash, & sand	23.8	30.8	8.4	2.0	16.2
Misc. (2" sieve)	28.3	26.9	35.0	37.0	31.8
Total	29.8	26.3	23.4	21.0	25.1

*Obtained by summing the weight of moisture in each week's samples by category of waste, and calculating percentages of the total weight of samples by waste category.

TABLE III-4
SEASONAL EFFECT ON ORGANIC CONTENT OF OCEANSIDE SOLID WASTE
(1971)

Category of waste	One week's average (percent dry weight) April	July	Oct.	Dec.	Weighted Average*
Garbage	87.8	85.7	83.6	74.4	82.9
Textiles	97.2	89.5	86.0	86.2	89.7
Grass	74.8	89.3	81.0	84.6	82.4
Wood	98.4	90.4	87.5	82.7	89.8
Newsprint	99.2	80.5	92.8	85.7	89.6
Cardboard	94.8	91.3	91.8	86.8	91.2
Misc. paper	93.3	88.7	88.4	86.1	89.1
Prunings, leaves	92.6	89.7	88.0	84.5	88.7
Foam plastic, rubber	--	96.8	73.3	98.3	89.5
Hard plastic, rubber and leather	--	89.5	--	96.0	92.8
Dirt, ash, & sand	4.1	30.5	13.4	8.6	14.2
Misc. (2" sieve)	--	61.7	31.3	66.8	53.3
Total	57.3	69.6	55.8	61.9	61.2

*Obtained by summing the weight of organics in each week's samples by category of waste, and calculating percentages of the total weight of samples by waste category.

TABLE III-5
COMPOSITION OF MUNICIPAL SOLID WASTES

Category of waste	Percent, wet weight		Santa Clara[#]	Long Island[**]	National Average[++]
	Oceanside[*]	Los Angeles[+]			
Newsprint	7.4	10.7	-	14.0	-
Cardboard	8.2	3.6	-	25.0	-
Miscellaneous paper	23.3	27.0	-	7.0	-
Total paper	38.9	41.3	55.0	46.0	48.0
Food	12.3	5.3	0.0	12.0	19.0
Glass & ceramics	10.6	7.3	0.0	10.0	8.0
Metals	7.1	6.0	8.0	8.0	9.0
Total vegetation (tree and shrub-prunings, grass & leaves)	12.4	33.1	34.0	10.0	4.0
Textiles	2.2	2.0	0.0	5.0	3.0
Hard rubber, leather, plastic	4.3	-	-	-	-
Foam rubber & plastic	0.2	-	-	-	-
Total rubber, leather, plastic	4.5	2.6	3.0	4.0	4.0
Wood	1.7	1.6	0.0	5.0	2.0
Dirt, sand, ash	0.5			0	3.0
Concrete, rock	0.4	0.8		0	0
Total soil, concrete, rock, ash	0.9	0.8	0.0	0	3.0
Other (2" sieve)	9.4	-		-	-

[*] Composited from four quarterly samples taken during 1971.

[+] Los Angeles, California (wet wt) as received 1/14/71 (88 loads).

[#] Santa Clara, California. From: Underground incineration of solid wastes. Ralph Stone and Company, Inc., U. S. Public Health Service Grant No. 1 GO6-EC-00190-01, July 1970.

[**] Long Island, New York (suburban, similar to Oceanside). Kaiser, Elmer. Thermal Processes for Refuse Reduction, presented at APWA, Institute for Solid Wastes, Annual Meeting, Boston, Mass., Oct. 1-5, 1967.

[++] Hickman, Lanier, Jr. Characteristics of municipal solid wastes. *Scrap Age,* Feb. 1969.

TABLE III-6
MOISTURE AND VOLATILE SOLIDS CONTENT OF OCEANSIDE SOLID WASTE FROM OLD LANDFILL SITE
(PLACED IN LANDFILL JANUARY 1963, SAMPLED SEPTEMBER 1971)

Category of waste	Content, percent dry weight	
	Moisture*	Volatile solids+
Newsprint	47.3	95.2
Cardboard	35.5	84.5
Grass	62.1	83.9
Leaves	61.7	83.9
Textiles	18.0	82.4

* Moisture content is the difference between sample after drying at 103C (dry weight) and as received total (wet) weight.

+ Volatile solids is the difference in weight between sample after drying at 103C and after burning at 600C.

3. Waste Generation. The quantity of solid waste produced in the City of Oceanside during four seasons of the year is given in Table III-7. The quantity generated during June exceeds the average of the quantities for January, March, and October, possibly due to increased summer tourist population and greater garden and other plant growth. The reason for variations in daily quantities between each season is not known. The solid waste daily average production was about 85 tons Monday through Friday, and about 25 tons on Saturdays.

A summary of the landfill vehicle counts is given in Table III-8. Loads of demolition wastes are tabulated separately as these materials were largely from highway construction and other special sources. The data for December was taken at the new City landfill which initiated operation on November 15, 1972. Private householders are generally not allowed to dispose at the new landfill site; commercial gardeners and those that deliver cover materials may unload at the fill. Of the total of 3,175 loads counted during 1971, 1,153 or 36.4 percent were delivered by private vehicles, and the Oceanside Waste Disposal Department accounted for 38.7 percent of the loads. The remainder of the vehicles were operated by the other City Departments. The types of solid wastes varied from normal household, commercial and industrial wastes to black top, dirt, gravel, street sweepings, brush, demolition, stoves, refrigerators, etc. Of course, the major solid waste volume and weight were delivered by the large Waste Disposal Department collection vehicles, rather than in the smaller vehicles of the other disposers.

B. Characteristics of Sewage Sludge and Septic Tank Pumpings

1. Types of Sewage Sludges. The Oceanside sewage treatment system employs three separate wastewater treatment works: the La Salina, Buena Vista, and San Luis Rey plants.

The La Salina Plant has a flow capacity of 5 mgd and provides primary settlement followed by secondary activated sludge units. The plant process units consist of primary clarifiers, aeration tanks, secondary clarifiers, heated two-stage sludge digesters. The digesters produce a final sludge with a total solids content varying between 3.9 to 5.4 percent, wet weight.

The San Luis Rey Plant has a design flow of 1.85 mgd (in 1971 it operated at around 50 percent of its design capacity). It provides treatment in a grit removal chamber, primary settling tanks, and a single-stage heated sludge digester. This plant also serves the limited but significant industrial wastes from plants in the City. The total solids content of the primary digested sludge varies from 3.3 to 8 percent, wet weight. The large variations are probably partially due to the variable flows from the industrial plants. The digested sludge from this plant tends to be more odoriferous than the digested activated sludges from the other two plants.

TABLE III-7
TOTAL WET WEIGHT OF SOLID WASTE PRODUCED IN OCEANSIDE
(1971)

Day	Weight, tons* January	 March	 June	 October	 Average
Monday	104.71	84.54	93.45	104.45	96.79
Tuesday	76.37	87.52	100.45	55.47	79.95
Wednesday	56.81	60.07	82.82	76.88	69.15
Thursday	78.03	84.65	88.83	65.71	79.31
Friday	103.29	99.24	130.62	109.27	110.61
Saturday	25.60	28.31	26.54	21.95	25.60
Total weight for the week	444.81	444.33	522.71	433.73	461.41 +

* Wet weight as received.

+ Estimated quantity of waste for 52 weeks is 23,992.8 tons per year.

TABLE III-8

OCEANSIDE LANDFILL VEHICLE LOAD COUNT
(1971)

Week total (1971)	No. of loads by vehicle type					
	Auto/trailer/ st. wagon	Truck, 1/4-1 ton pick-up/ van	Truck, over 1 ton	Oceanside waste disp.	Municipal other	Total
February	21	69	40 (49) *	117	14	261 (310)+
March	3	38	25 (4)	136	47	249 (253)
April	14	83	77 (129)	134	28	336 (465)
May	12	81	86 (21)	135	14	328 (349)
June	4	48	74 (127)	91	0	217 (344)
July	7	106	52 (13)	125	1	291 (304)
August	9	83	8 (55)	121	7	228 (283)
October	18	110	74 (6)	126	3	331 (337)
November	8	71	36 (27)	123	12	250 (277)
December	0	91	29 (0)	121	12	253 (253)
Total veh. loads	96	780	501 (431)	1,229	138	2,744 (3,175)

* ( ) = Loads of demolition waste.

+ ( ) = Total including demolition waste.

The Buena Vista Plant is the smallest of the three plants with a design flow of 0.5 mgd, and it provides activated sludge treatment and sludge digestion similar to the La Salina Plant. The treatment process consists of a combination primary clarifier-aeration tank (Clarator), a secondary clarifier, and a heated sludge digester. The total solids content of the single stage digested sludge varies widely from 2.3 to 11.2 percent, wet weight.

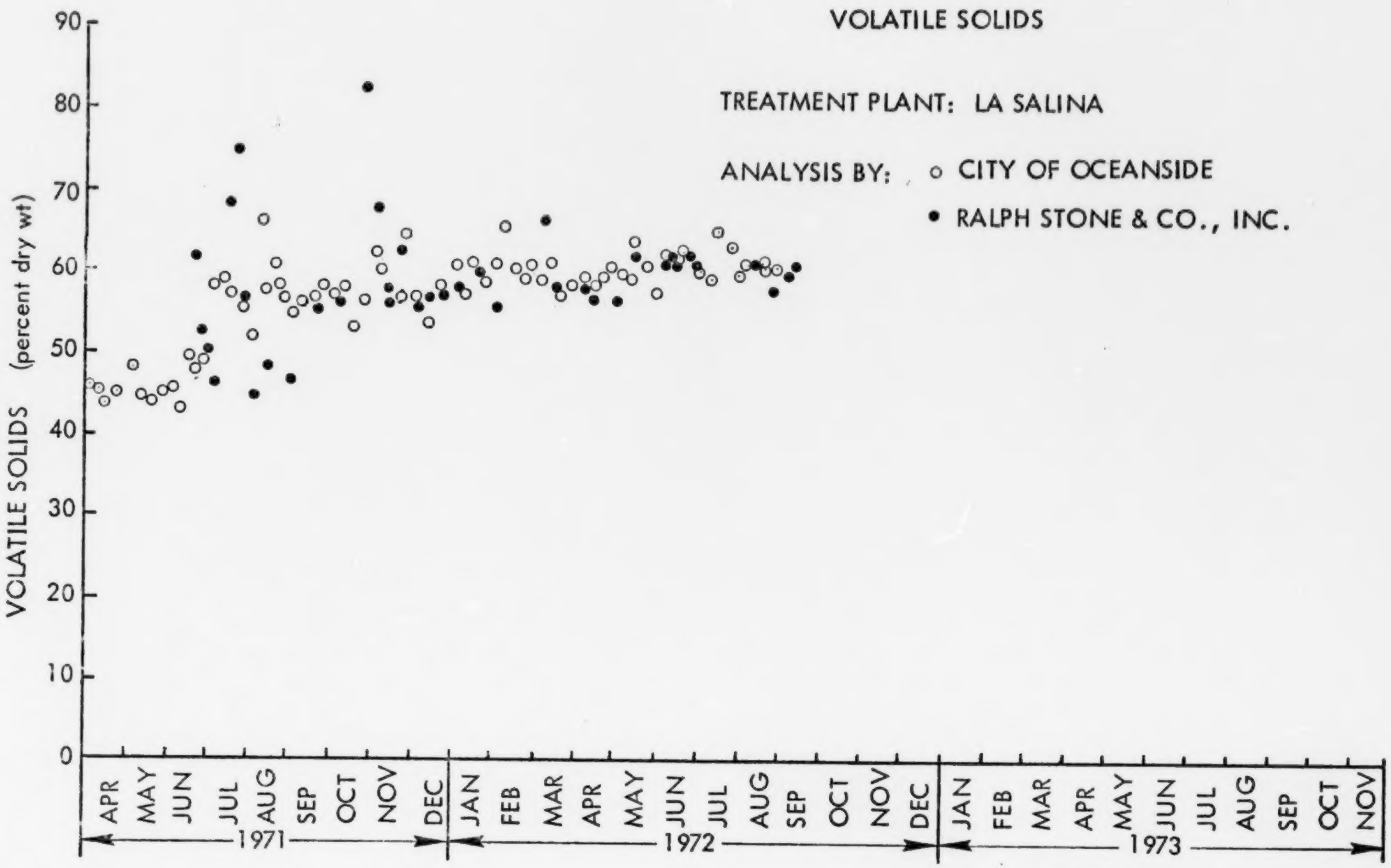
Both the old San Luis Rey and Buena Vista Plants are scheduled to be closed down by 1975 when construction of a new San Luis Rey Plant should be completed to provide integrated tertiary treatment.

2. Sewage Sludge Characteristics and Quantities. Routine analyses were performed on sludge samples from all three treatment plants by both the City of Oceanside and Ralph Stone and Company, Inc. All of these tests have been plotted to show trends since the inception of the project; the plotting of the sludge data will continue throughout the remainder of the study. The results of these analyses are discussed below. All analytical methods used for sludge analyses were in accordance with Standard Methods,[3] 13th Edition, where applicable (see Appendix A).

The data on total solids and volatile solids for each of the treatment plants are shown in Figures III-1 through III-6. The data in these figures indicate a range of about 2 to 10 percent for over one year operation, with about 30 to 70 percent volatile solids based on dry weight; there was lesser variation in total solids or volatile solids content in the La Salina and San Luis Rey Plants' sludges.

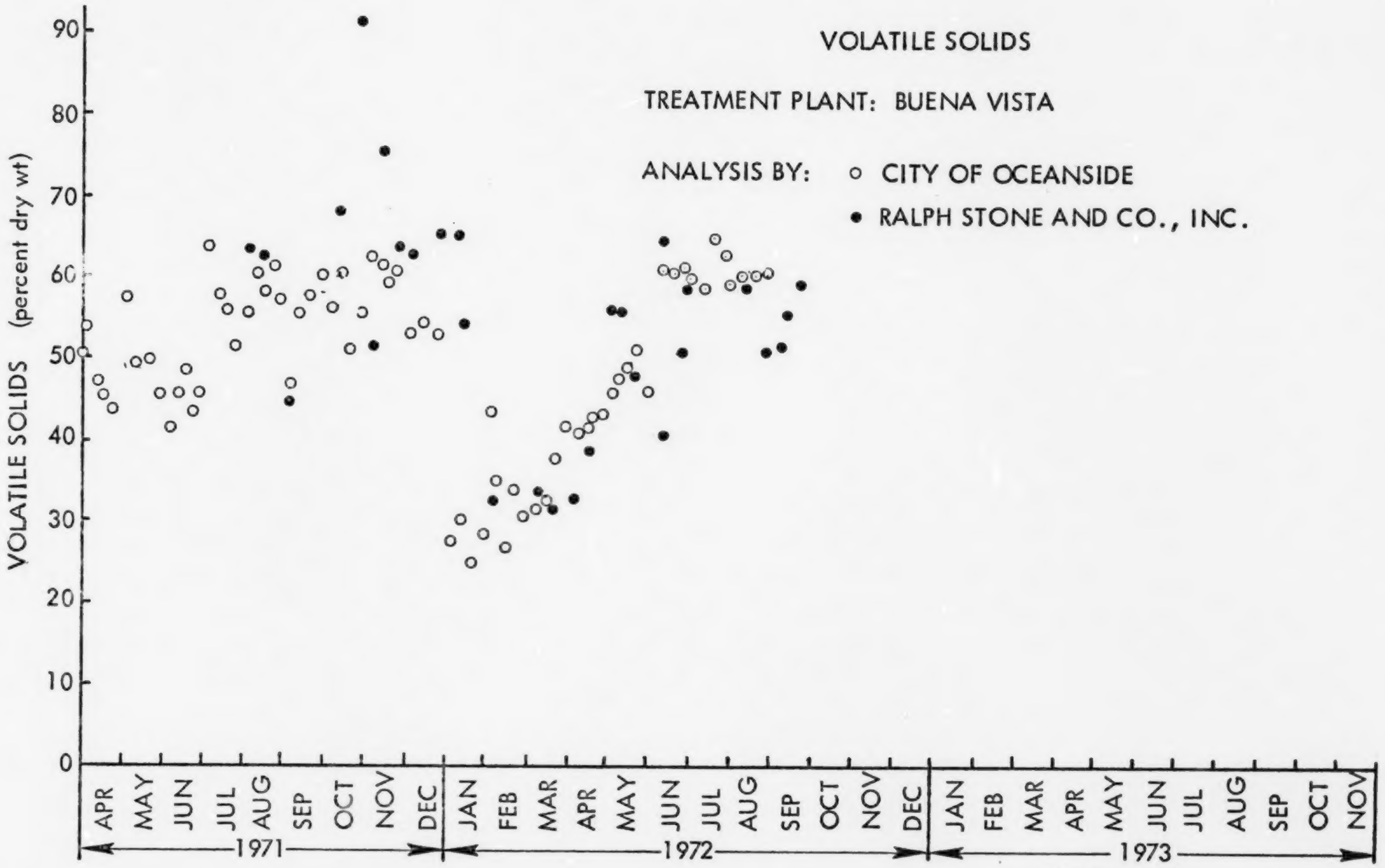
The quantities of sewage sludge hauled for disposal from the three municipal sewage treatment plants are summarized in Table III-9. The sludge production was projected based on estimated raw sewage volumes and characteristics for the existing and planned sewage treatment plants providing activated sludge treatment of the total wastewater flow with normal sludge digestion efficiency. The projections are given in Table III-10.

3. Characteristics of Septic Tank Pumpings. The differences and similarities between septic tank pumpings and digested liquid sewage sludges are of importance from the standpoint of landfill disposal. Septic tank pumpings may be expected to show a far wider variability in their composition thandigested municipal sludges. Septic tank pumpings were used in the present study in connection with the pilot-plant landfill simulation experiments (see Chapter VI). The pouring and penetrating properties of these pumpings were noted to be significantly different from those of digested municipal sewage sludges. One of the septic tank samples analyzed was thin, having a BOD_5 of only 130 mg/l and flow viscosity characteristics essentially the same as water. A thicker sample showed a BOD_5 of 1,630 mg/l, which would be fairly low for a municipal sludge, and about 2 percent total solids. Most significant was the nature of the solids: they were more granular and faster-settling than the solids of municipal sludge, having negligible effect on the flow characteristics of the liquid.



CITY OF OCEANSIDE/E.P.A.

FIGURE III-1
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



CITY OF OCEANSIDE/E.P.A.

FIGURE III-2
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

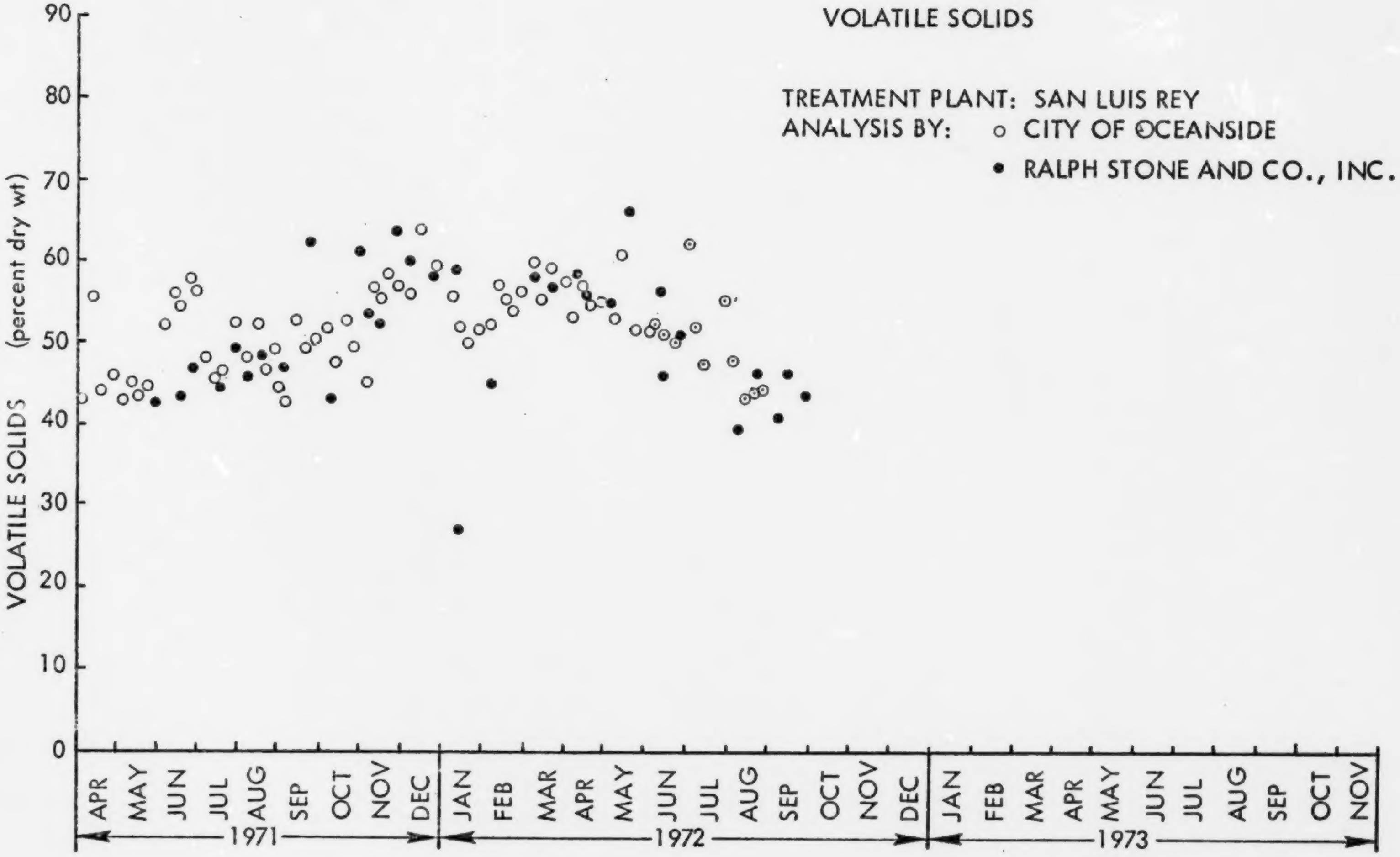


FIGURE III-3
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

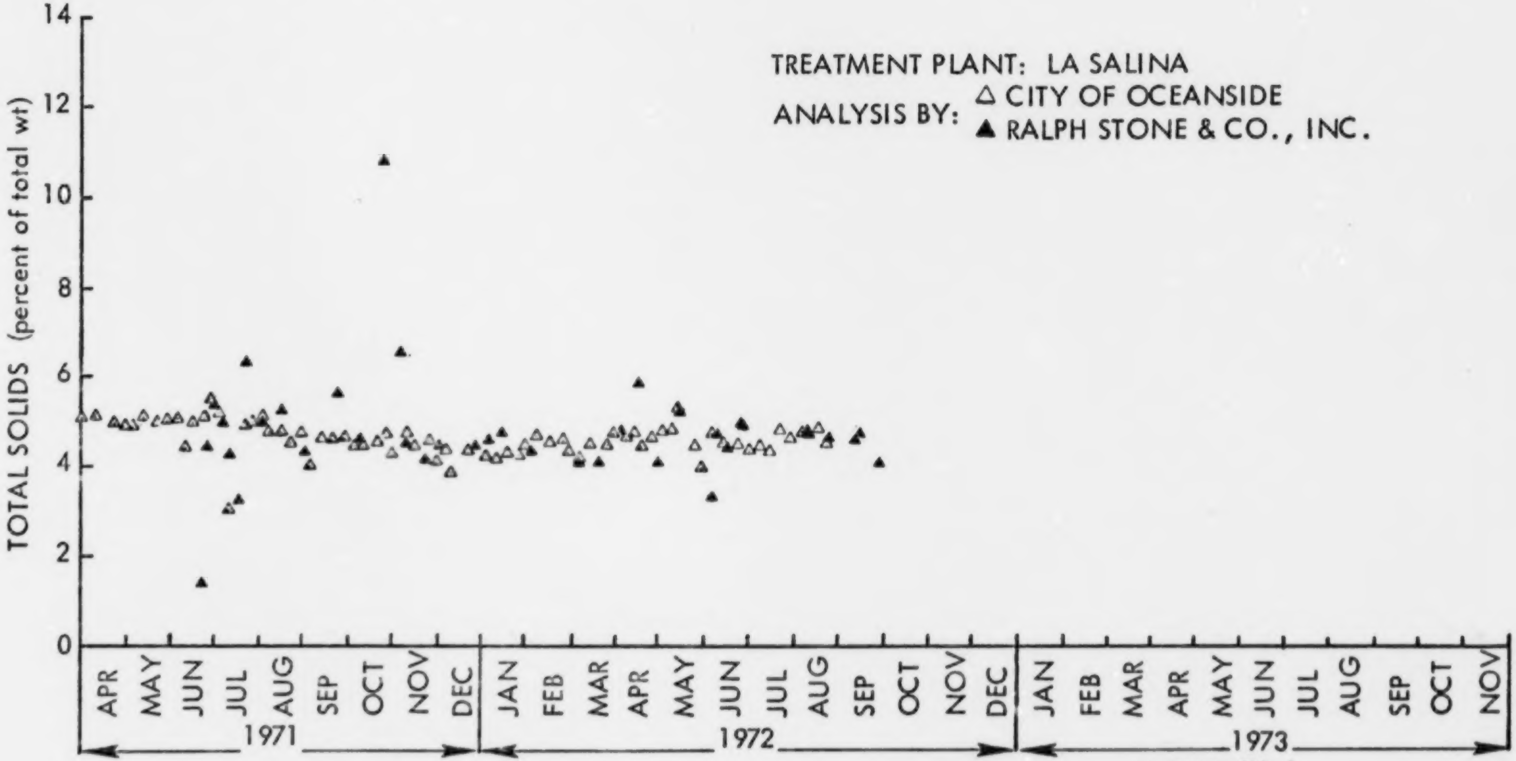
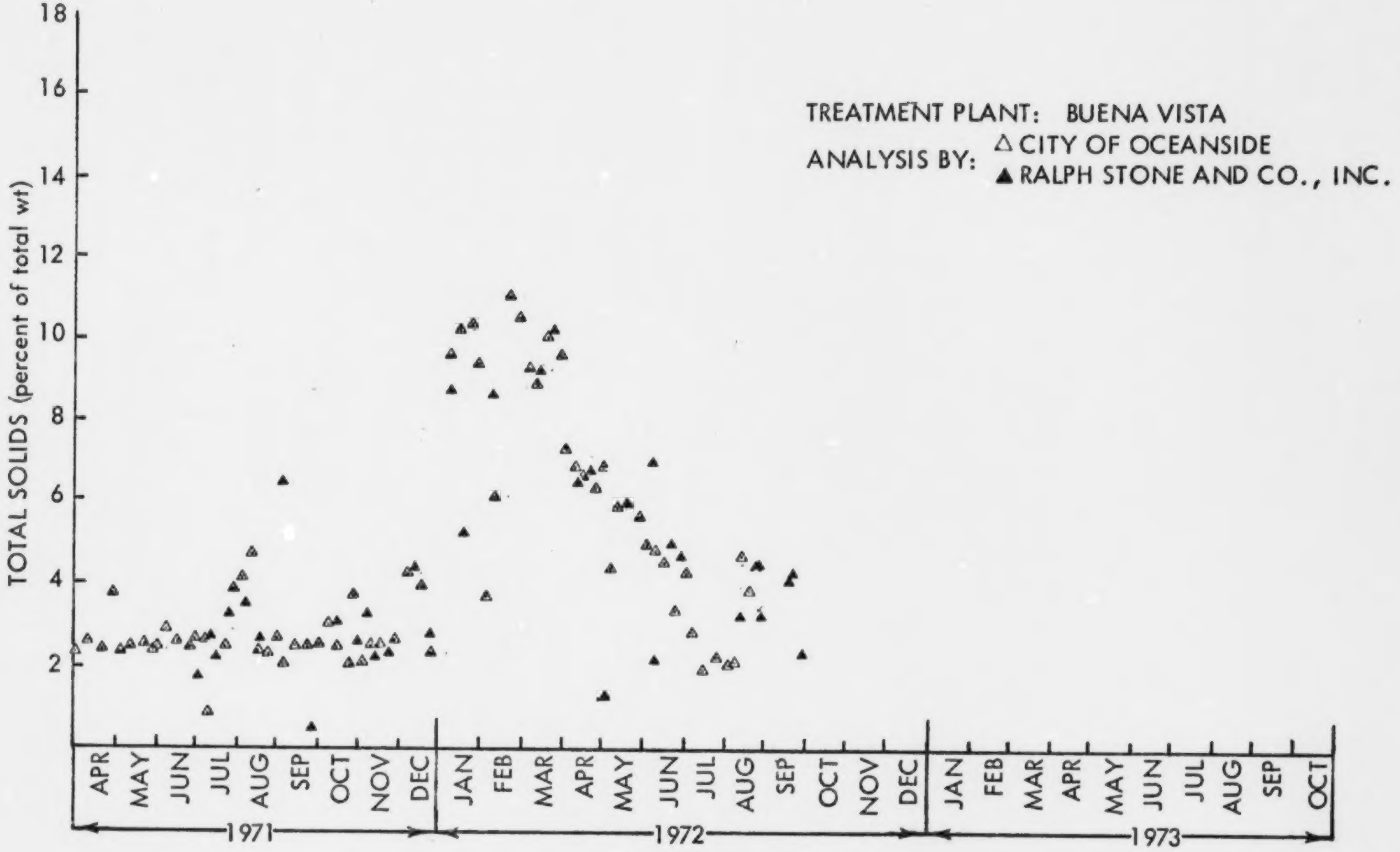


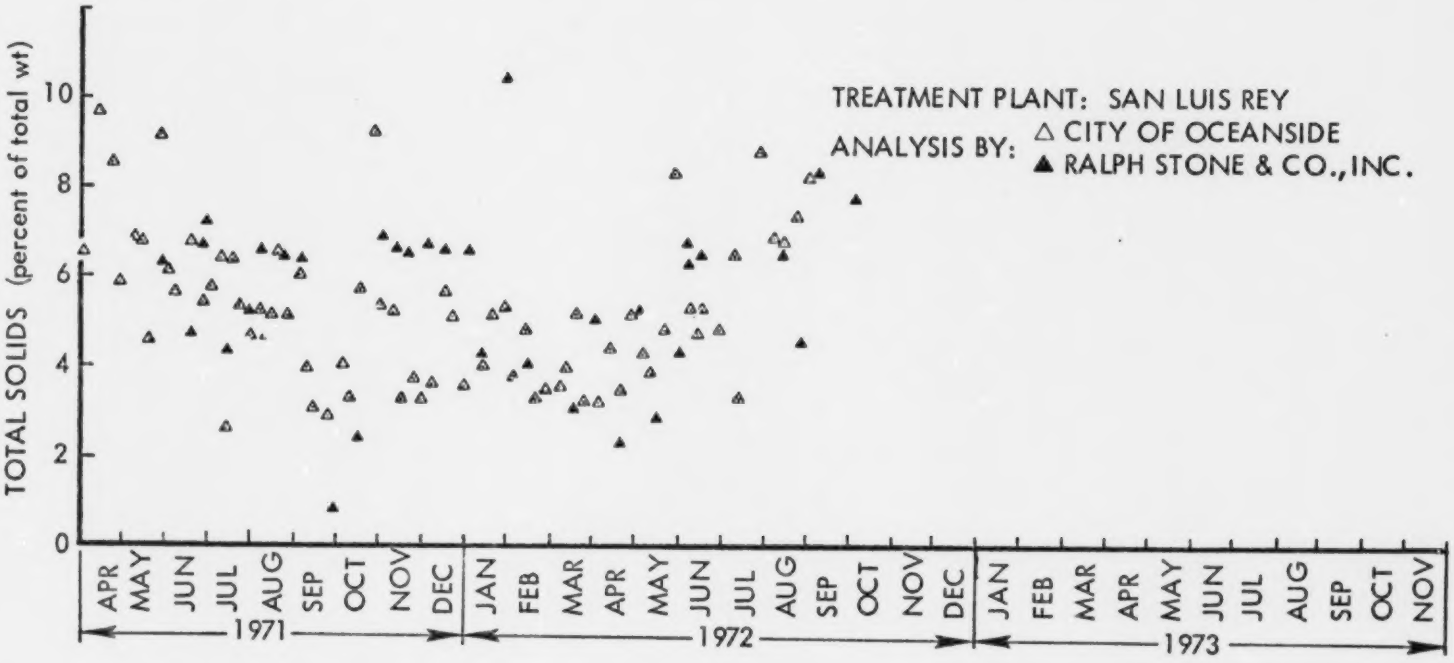
FIGURE III-4
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

CITY OF OCEANSIDE/E.P.A.



CITY OF OCEANSIDE/E.P.A.

FIGURE III-5
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



CITY OF OCEANSIDE/E.P.A.

FIGURE III-6
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TABLE III-9
SLUDGE HAULED FOR DISPOSAL

Month	La Salina	Gallons per plant Buena Vista	San Luis Rey	Total
1971				
Jan	133,000	49,000	21,000	203,000
Feb	162,000	52,000	24,000	238,000
Mar	108,000	68,000	35,000	211,000
Apr	63,000	78,200	45,500	186,700
May	56,000	84,000	52,500	192,500
June	59,500	66,500	50,750	176,750
July	63,000	63,000	59,500	185,500
Aug	68,250	70,000	64,750	203,000
Sep	56,000	56,000	63,000	175,000
Oct	81,000	71,500	45,500	198,000
Nov	91,000	59,500	45,500	196,000
Dec	59,500	21,000	35,000	115,500
Total	1,000,250	738,700	542,000	2,280,950
1972				
Jan	91,000	56,000	38,500	185,500
Feb	66,500	101,500	35,000	203,000
Mar	101,500	31,500	38,500	171,500
Apr	178,500	17,500	42,000	238,000
May	210,000	38,500	85,500	334,000
June	188,000	83,500	36,500	308,000
July	234,500	80,500	31,500	346,500
Aug	234,500	77,000	38,500	350,000
Sep	220,500	91,000	56,000	367,500
Oct	102,000	75,500	50,000	227,500

TABLE III-10
PROJECTED TOTAL SLUDGE QUANTITIES REQUIRING DISPOSAL

	Year 1985		Year 2000	
Sludge wet weight)	(1,000 gal/day)	(million gal/yr)	(1,000 gal/day)	(million gal/yr)
Fresh sludge 3.5-4.5 percent solids	60	22.0	80	29.2
Digested sludge 5.0-6.0 percent solids	29	10.6	38	13.9

Conductivities of the particular septic tank pumpings from outlying areas were 1,900 and 1,200 μmhos for the thick and thin pumpings, respectively, whereas the Oceanside sewage sludge was considerably more saline with 3,190 to 4,200 μmhos.

4. Analysis of a Composite Sewage Sludge Sample for Heavy Metals. A knowledge of the concentrations of various trace metals present in sewage sludge is essential for proper evaluation of the potential for groundwater pollution through leaching or pollution of surface waters through runoff. Since these analyses were too costly for numerous individual samples, a composite sample was made by taking 50 ml portions from all bi-weekly sludge samples received from the three Oceanside treatment plants during 1971 (see also Chapter VI). The ratio of the sludge production from the three plants' contributions to the composite were approximated for the La Salina, Buena Vista, and San Luis Rey sites, respectively. The results of these analyses are presented in Table III-11. Other composited samples are being analyzed for 1972 and also for 1973.

The concentrations for lead, chromium, and mercury (toxic heavy metals) were less than 0.1, 0.01 and 0.1 mg/l respectively. It should be noted that these concentration levels represent the detection limits of the analytical techniques used and not the actual concentrations of the heavy metals. It is entirely possible that the actual concentrations were significantly lower than the indicated detection limits. Heavy metals in sewage sludges usually originate in industrial wastes discharged into the municipal sewerage systems. Since industrial wastes do not account for a significant portion of the total wastewater flow in Oceanside, the sludges from Oceanside plants would not be expected to contain significant quantities of heavy metals. (Sludges from certain municipal plants serving highly industrialized urban centers often contain appreciable amounts of heavy metals.) Even if a sludge does contain high concentrations of heavy metals, not all the heavy metals may be leached out from the landfill. Considerable heavy metal content may also be present in normal or industrial solid waste disposed into a landfill.

TABLE III-11

CHEMICAL ANALYSIS OF SLUDGE COMPOSITE* SAMPLE, FROM OCEANSIDE TREATMENT PLANTS (1971)

Element present	Concentration (mg/l)
Copper	3.0+
Iron	0.16+
Fluorides	1.1#
Lead	<0.1+
Mercury	<0.1+
Chromium	<0.01+
Chlorides	400#
Hardness as calcium carbonate	344#
Calcium	138+

* Composite was compiled from 100 ml portions taken from bi-weekly samples of sewage sludge from each of the three Oceanside treatment plants.

+ Analyses by atomic absorption per Standard Methods, 13th Edition.

# Analyses as follows per Standard Methods, 13th Edition: flourides - SPADNS Method, Sec. 121C, p. 174.; chlorides - Argentometric Method, Sec. 112 A, p. 96; calcium carbonate-calculation method, Sec. 122A, p. 179.

IV. SOLID WASTE WATER ABSORPTION STUDIES

A. Purpose and Scope

The water retention or field capacity of municipal solid waste in a landfill is of considerable importance in that it determines the amount of leachate that may result from a given amount of rainfall, or other source of water. Sanitary landfills may offer convenient and environmentally preferable disposal sites for liquid digested sewage sludge, particularly in dry climates. Some of the major factors to be considered in the design and operation of a combined sludge-solid waste landfill disposal system include: the quantity and characteristics of solid waste and sewage sludge generated by a community, the annual rainfall, and the maximum storm intensity. The composition range of municipal solid waste may be ascertained by standard sampling techniques; the results of such analyses are available for several communities. Similarly, the tonnage of solid waste and sewage sludge produced and the pertinent rainfall data can be determined or estimated for each community. To predict the quantity of sludge that could be applied to a landfill without exceeding its water retention capacity, data are needed on the absorptive capacities of the various component waste substances. Since such data have been heretofore lacking, laboratory tests were conducted to obtain data on absorption for substances commonly found in municipal solid waste. The physical properties evaluated were the saturation capacity, expressed as grams of water per gram of dry weight sample material, and the rate of absorption, expressed as the time required for an immersed sample to approach saturation. As discussed in subsequent chapters of this report, the laboratory test results were later evaluated in pilot-scale and field demonstration landfill tests.

B. Factors Affecting Absorption

The absorption of water from liquid sludge by the solid waste is affected by the physical and chemical (material) properties of both the sludge and the solid waste components. The important physical properties of a solid waste component are surface characteristics, shape, and size (dimensions). In general, the saturation capacity is a property of each solid waste component material, independent of size or shape, whereas the rate of absorption is affected by the material properties, the internal structure of the sample particle, and its minimum dimension. In the case of cloth, paper, and grass, the minimum dimension (i.e., thickness) is negligible with respect to water passage, therefore, the rate of absorption may be effectively treated as a material property. For wood or soil, however, the rate at which a sample approaches saturation varies over a wide range, depending upon the minimum dimensions of the wooden object or depth of the mass of soil considered. In other words, the time required for the center of a piece of wood or soil sample to approach saturation is roughly proportional to the minimum distance to be traveled by the water soaking through it, while a sample of cloth or paper, being of negligible thickness, will become saturated in a fixed and characteristic time interval regardless of the area of the sample. Wetted materials that are hydroscopic, permeable and with a large surface area to volume ratio will reach field capacity more quickly than materials with contrary characteristics. This distinction should be kept in mind when comparing the water absorption properties of different materials.

The nature and arrangement of the solid waste components also affect the rates of travel and absorption of water and the quality of the leachate. A small but unpredictable amount of water may be retained through interstitial entrainment of liquid in voids between particles. The extent of liquid entrainment is a function of the size, shape, and arrangement of solid waste component particles, and the viscosity of the liquid. The rate of travel of the liquid through solid waste depends on three factors, the hydraulic pressure, the size of the voids between particles and the capillary action. The liquid flows via gravity fairly rapidly through large voids and thus can by-pass absorption onto surfaces; it also moves by capillary action through the materials at a slower rate dependent on the intercellular structure of the materials. When a liquid wets a solid, there exists a greater attraction between the liquid and the solid than between particles of the liquid; e.g., adhesion is stronger than cohesion. The adhesive attraction of water and liquid sludge for the majority of solid waste components provides the capillary mechanism by which these liquids travel and disperse through a landfill.

C. Laboratory Test Procedures

To determine the field capacity of the municipal solid waste materials for absorption of water, representative samples of typical solid waste components were immersed separately in water for varying lengths of time. The following substances were used: pulp and paper products (toilet tissue, paper towel, newsprint, corrugated cardboard, solid cardboard, and glossy magazine paper); wood (plywood, sticks and blocks); textile and related products (cotton, wool, synthetics, hemp, nylon, and leather); vegetation (garden trimmings such as live leaves, dead leaves, twigs from branches), and kitchen garbage (orange, banana and grapefruit peels).

Except for some plant samples which were immersed enclosed in a wire mesh basket, all test samples were immersed by suspending them from wire hangers into one-liter beakers filled with water. All tests were performed at ambient temperature (20± 2 C). For each material and immersion interval, three separate identical samples were used. The three samples were immersed in water as received; e.g., the samples were in the wet weight condition as normally received in a landfill. A fourth sample was dried overnight at 100C and weighed to determine initial moisture content and dry weight. The amount of water absorbed by each test specimen was determined by subtracting the as-received (wet) weight from the weight after immersion. The moisture absorbed on a dry weight basis was calculated by dividing the water absorbed by the dry weight of each sample material. The "after-immersion" weights for the paper samples were determined after the samples were drip-dried for a sufficient length of time so that no water drop would occur after one minute. In the case of cloth samples, the specimens were weighed after they were lightly wrung between rolls to the extent that they slightly wetted the fingers when touched, but did not drip. Following immersion, the garden trimmings' samples were shaken and slightly blotted to dry their surfaces before weighing.

In the laboratory tests, less-absorbent waste constituents such as rock, concrete, metal, glass, hard plastic, ceramics, and rubber were not tested for moisture absorption. Soil, (dirt, sand, ashes, etc.) which may be considered an inert material (and which is used to cover the consecutive strata of solid waste in a landfill), was tested for its capacity to entrain water in its pore, and for water percolation rates.

The following types of soil and soil-related materials were used in the laboratory tests: loam, clay (of marine sedimentary origin), Ottawa sand, humus (domestic garden compost), and charcoal ash (from barbecue charcoal briquettes). The maximum water-holding capacity of each sample was determined as follows. A small plastic cup containing the sample saturated with water, was allowed to stand until the rate of dripping from an orifice in the bottom became negligible. The moist sample was then weighed, dried for 24 hrs at 200 F and weighed again. The saturated sample weight loss was reported as a percent of the final (oven-dry) weight.

The soil percolation experiments were conducted on loam and clay only. Prior tests have been completed with sandy soils which, obviously, have higher permeability. (Loam and clay account for typical common soils available at municipal landfill sites.) The loam samples were pulverized to varying fineness in order to obtain samples having a wide range of bulk specific gravities. The percolation experiments involved measuring the time required for downward movement of water through a 7 1/2-inch column of soil, 1-inch in diameter, under a constant head of 2-inches above the top of the column. The escape of the first drop of water from a screen at the bottom of the column was recorded to establish the percolation rate.

D. Results and Discussion

1. Water Absorption by Solid Waste Components. Figures IV-1 through IV-5, and Table IV-1 show the laboratory test data for the absorption of water by a variety of waste components. In these figures, the quantity of water absorbed expressed as percent of oven-dry weight above the initial as-received wet weight of the samples is plotted as a function of the immersion time. In cases where the spread in data for several samples was great, the envelope curves were drawn through the lowest absorption value, thus providing conservative absorption ranges. As indicated in Figure IV-1, the rate of absorption of water and the maximum absorption capacity varied widely with different types of paper products. For the samples tested, the water absorbed varied from 120 percent for the glossy magazine paper to more than 700 percent for the toilet tissue. The rate of water absorption was also higher for the toilet tissue than for any other type of paper tested. In all cases, however, maximum or equilibrium absorption capacity was attained in less than 40 minutes. Except for paper towel samples, which showed some variation in their absorption capacity, the results were consistently reproducible for similar paper products tested.

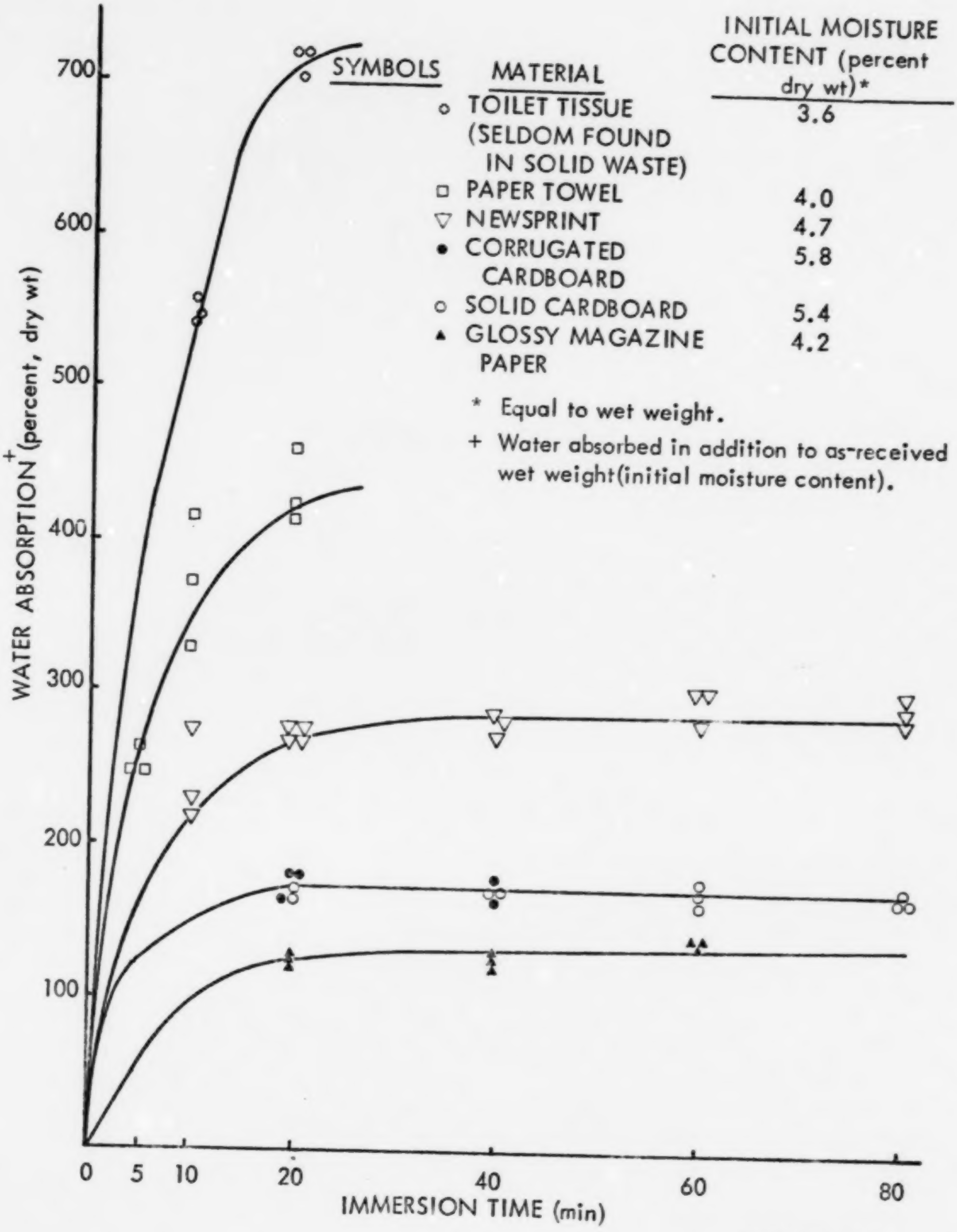


FIGURE IV-1

WATER ABSORPTION OF PAPERS

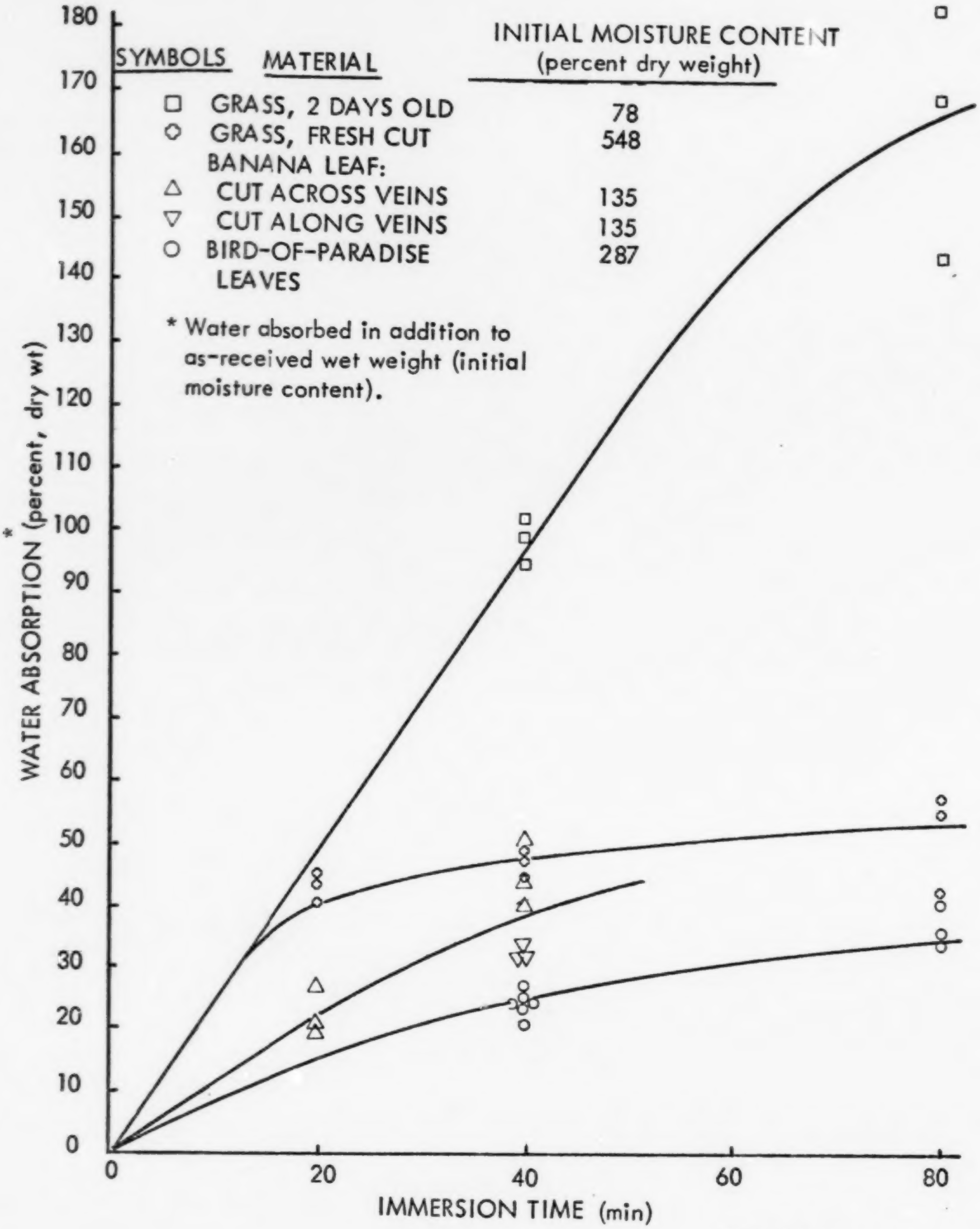


FIGURE IV-2
WATER ABSORPTION OF
PLANT TRIMMINGS (GRASS AND
OTHER MONOCOTYLEDONS)

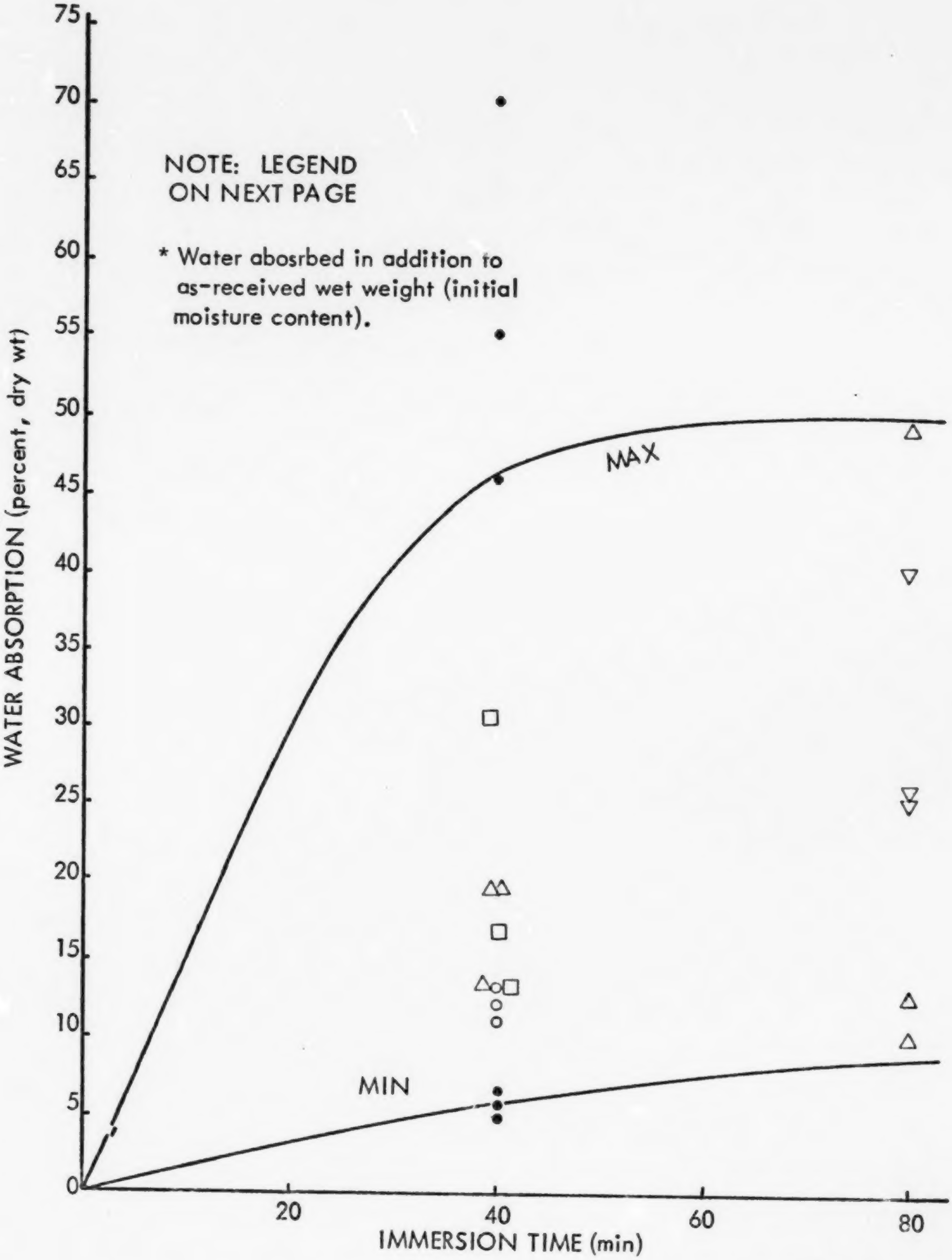


FIGURE IV-3
WATER ABSORPTION
OF PLANT TRIMMINGS
(WOODY SHRUBS)

SYMBOLS	MATERIAL	INITIAL MOISTURE CONTENT (percent dry weight)
•	PRIVET EVERGREEN: NEW GROWTH ONLY.	190
MAX MIN	RANGE OF FOLLOWING:	
•	BAY TREE: DEAD LEAVES ONLY.	4
○	TWIGS ONLY	35
□	IVY	296
▽	JUNIPER	96
△	PODOCARPUS	179

* Water absorbed in addition to as-received wet weight (initial moisture content).

FIGURE IV-3
(LEGEND)

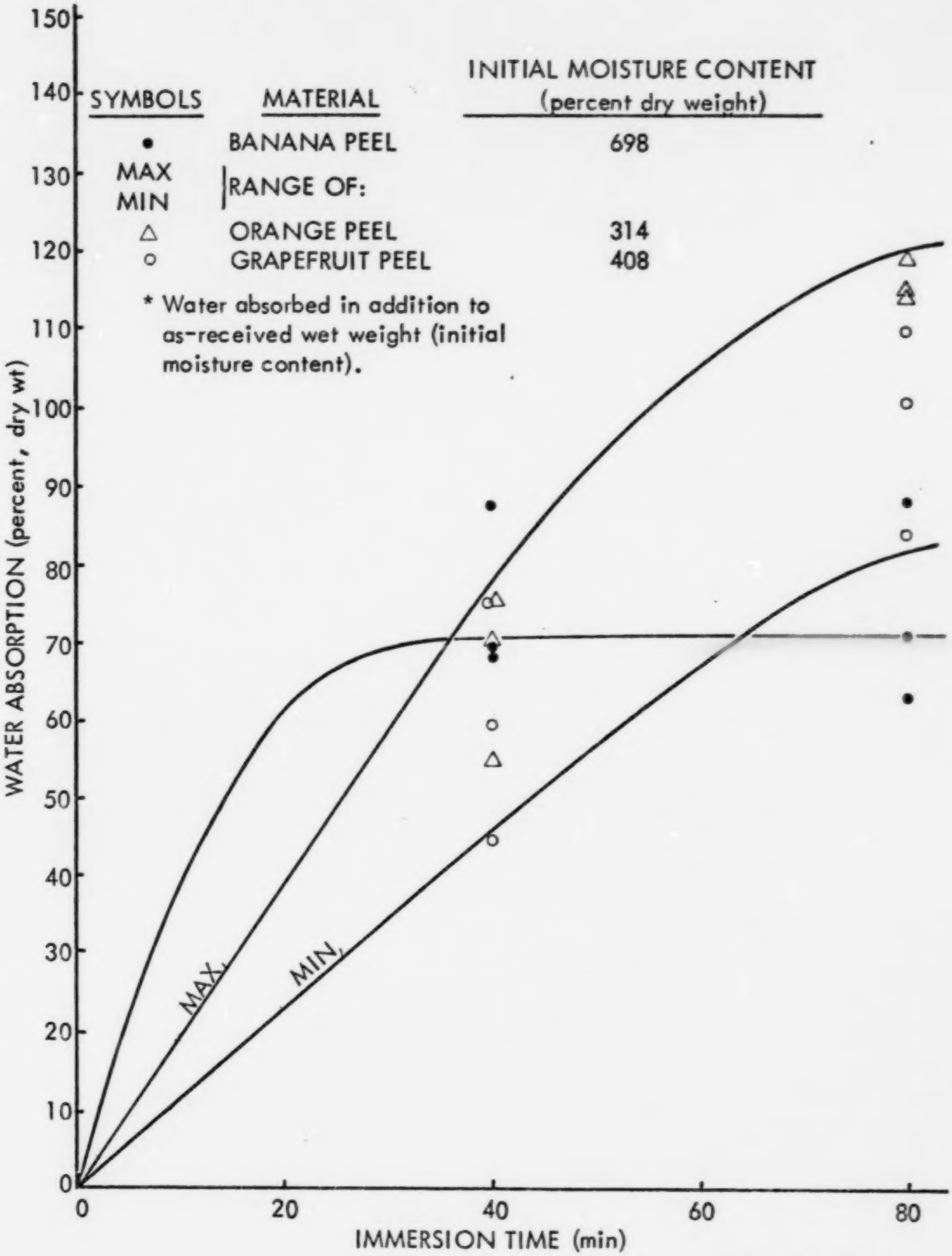


FIGURE IV-4
WATER ABSORPTION
KITCHEN GARBAGE
(VEGETABLE)

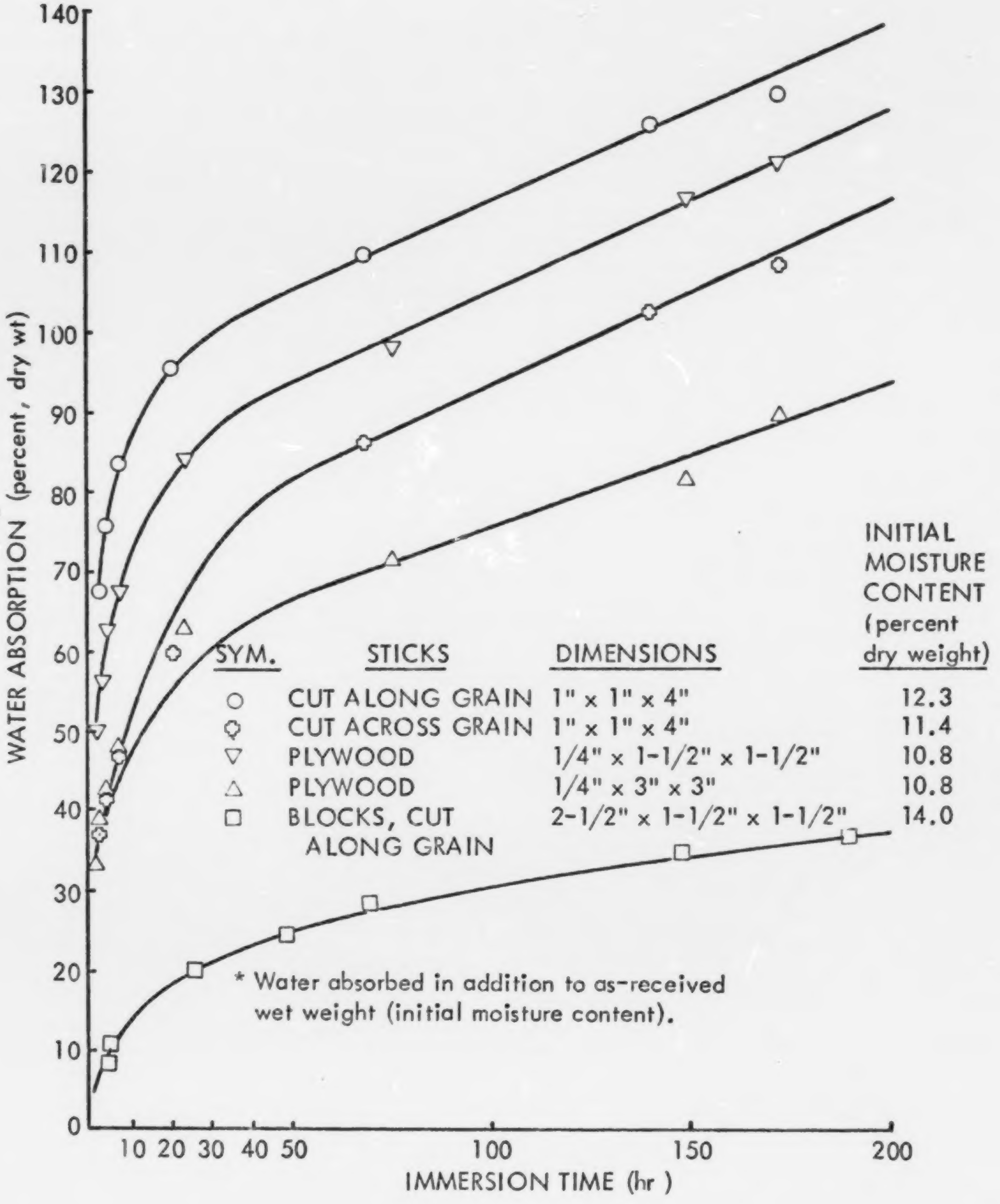


FIGURE IV-5
WATER ABSORPTION
IN WOOD

TABLE IV-1
MOISTURE ABSORPTION BY TEXTILES AND LEATHER

Item	Water absorbed	
	Average* (percent dry weight)	Maximum variation from average percent
Cotton (T-shirt)	313	+23
Cotton (towel)	409	+18
Wool	185	+ 3
Acetate or similar synthetic		
Wool-like, double-knit	194	+13
Silk-like, light weight	165	+ 8
Hemp rope	129	+40
Nylon rope	41	+14
Leather	42	+15

* Average of three or more replicate measurements. Saturation was reached in 10 minutes or less, thus no characteristic curve was generated. Water absorbed in addition to as-received wet weight (initial moisture content). Initial moisture content of these materials (less than 3 percent dry weight) was less than the data variation and, therefore, the average water absorbed is the total absorption capacity.

Figures IV-2 and IV-3 present the absorption test results for plant trimmings (monocotyledons and woody shrubs, respectively). As with the paper products, different plant materials appear to have a range of capacities for water absorption. For example, with an immersion time of 40 minutes the quantities of water absorbed were 5, 50 and 100 percent for juniper trimmings, freshly cut grass, and 2-day-old cut grass, respectively. Cutting along banana leaf veins on one sample produced little difference in absorption from cutting across the veins; thus the samples cut across veins were used as representative of banana leaf. Considering that the lawn clippings are among the most common plant components in municipal solid waste, and that plant cuttings may account for as much as 35 percent of the residential solid waste, the significance of storage time (drying) in relation to overall water holding capacity of solid waste becomes apparent. The data in Figures IV-2 and IV-3 indicate a lack of good reproducibility for experiments with woody shrub trimmings and 2-day-old cut grass. This lack of reproducibility may be due (in part) to some degree of non-homogeneity in the drying of the vegetation.

Figure IV-4 indicates a range of water absorption capacities for the common fruit components of kitchen garbage (banana, orange and grapefruit peels). The water absorption data for five different wood specimens are presented in Figure IV-5. The data in this figure indicate that in contrast to plant trimmings and fruit waste (Figures IV-1 through IV-4) which become saturated with water fairly quickly, an immersion time of greater than 200 hr was required for the saturation of the wood specimens tested. The data in Figure IV-5 indicate that on a percent dry-weight basis and for a contact time less than that required for complete saturation, the quantity of water absorbed by a piece of wood is affected both by the type and the dimensions of the specimen. For example, for an immersion time of 50 hr, a 1-1/2 x 1-1/2 x 1/4-in. piece of plywood holds approximately 46 percent more water per unit dry weight than a 3 x 3 x 1/4-in plywood specimen. Because of the slow rate of water absorption, the ultimate absorption capacity of wood will require a considerable number of days' exposure in a combined liquid sludge-solid waste landfill operation. The water in the liquid sludge added to fresh lumber waste would tend to percolate down or be absorbed by other more absorbent components of the solid waste at a faster rate than it could be absorbed by bulky wood waste components.

Absorption experiments with cotton and wool samples indicated no significant change in the quantity of water absorbed when the immersion time was increased from 10 to 20 minutes. This indicates that textile materials such as cotton and wool saturate more rapidly than other waste components. Table IV-1 presents absorption data (20-minute immersion) for leather and various textile products tested. Due to the short time to reach moisture saturation for items in Table IV-1 (10 minutes), a time-absorption characteristic curve was not generated. On a dry-weight basis, the quantity of water absorbed ranged from 41 percent for nylon rope to 409 percent for cotton toweling.

The rate of absorption of water by an isotropic water-absorbing substance may be approximated heuristically by a first-order reaction equation $y = y_m (l-e^{-kt})$ where y_m = saturation (maximum) moisture content, y = moisture content at time t, and k is a constant the magnitude of which is dependent on the type of material, the liquid properties, the surface area of the material and the grain or fiber direction relative to surface area. The experimental data presented above for paper products follow a curve characteristically described by the exponential absorption equation. For other wastes tested, however, the conformity is not very good and this may be attributed to the non-isotropic nature of the test specimen (e.g., in the case of wood) and to non-homogeneity of the sample (e.g., in the case of plant trimmings).

2. Water-Holding Capacities of Soil and Related Materials. Table IV-2 presents data on the water-holding capacities of loam, humus, sand, charcoal ash, and clay. The samples show minor variation in the three replication runs for each material.

The data in Table IV-2 indicate significant differences in the water-holding capacity of various soils. Based on average values, the water-holding capacity ranged from 15.7 percent for sand to 94.5 percent for humus. The relatively high water-holding capacity of the soil humus may be attributed to its small pores and high organic/cellulose characteristics.

The results of percolation tests for fine loam, fine clay, and coarse clay are presented in Table IV-3. The data in Table IV-3 indicate a significantly larger percolation rate for the fine loam samples than for either of the clay specimens. The percolation rates ranged from 0.94 to 1.58 inches/minute for loams and from 0.19 to 0.554 inches/minute for clay. For each test specimen a rate factor was calculated by dividing the observed percolation rate by its bulk specific gravity. The rate factor was used to determine if a correlation existed between bulk specific gravity and percolation rates for a given soil. None was found. For the two types of soil used and for the range of bulk specific gravities considered, the nature of the soil appears to have a greater influence on the percolation rate than its bulk specific gravity.

From the data in Table IV-3, it is apparent that the difference between clay and loam is significant, but the permeability of either cannot be controlled appreciably by the degree of compaction, beyond assuring that all large void channels are eliminated. In-house studies, not presented here, have shown that downward percolation through lightly compacted solid waste, sand or gravel may easily be more than an order of magnitude greater than the above figures for loam.

The soil cover strata in a landfill would be expected to provide three important hydrological functions: 1) Generous layers of loam or clay would significantly increase the liquid retention capacity per volume of completed landfill; 2) These layers with even poor compaction may retard the downward percolation, thereby increasing the time available to each layer of refuse to absorb the maximum possible amount of liquid; 3) The solids in sludge, that may flow through the interstices of municipal refuse, would be effectively stopped by filtration through layers of soil, and reduce the soil permeability still further by filling the intergranular pores. These phenomena could turn into a liability under some conditions. For example, if a heavy rain and sludge application occurred on a sloping landfill face, especially if the cover soil is clay, the relatively impermeable strata could force lateral, or diagonal percolation of thin sludge and rain water to the bottom of the working face, instead of downward through lower strata of the fill.

TABLE IV-2
WATER-HOLDING CAPACITY OF TYPICAL SOILS

Material	Fine, sandy loam	Natural humus	Ottawa sand	Charcoal ashes	Clay
Organic content (% of dry weight)	4.87	17.65	-	-	5.77
Saturation moisture content (% of dry weight)	44.3	104.0	15.3	71.8	31.5
	40.4	87.6	15.6	71.2	32.5
	42.5	92.0	16.1	69.5	31.0
Average	42.3	94.5	15.7	70.8	31.7

TABLE IV-3
SOIL PERCOLATION RATE CORRELATIONS

Soil sample	Bulk specific gravity	Percolation rate (inches/min.)	Rate factor*
Fine loam (moisture content, 14.9% dry wt)	0,991	1,15	1,16
	1.084	0.98	0.90
	1.142	0.94	0.82
	1.166	1.25	1.08
	1,196	1,58	1,33
	1,240	0.83	0.67
	1,336	1.16	0,87
Fine clay (moisture content, 5.19% dry wt)	1.486	$0.19^{\pm}$	-
Clods of clay (moisture content, 5.19% dry wt)	1.407	0.554	0.39
	1.340	$0.25^{\pm}$	0.19

* Rate factor = percolation rate/bulk specific gravity.

3. Prediction of Sludge Retention Capacity for Oceanside Solid Waste.

Based on the aforementioned laboratory results for the absorption of water by various solid waste components, rough estimates may be made of the liquid sludge capacity of municipal solid wastes of known compositions.

A review of the data in Figures IV-1 through IV-5, and Table IV-1 indicates that for newsprint, cardboard, miscellaneous paper and textiles the as-received (initial dry weight) moisture content of the samples was less than the variation in absorption between samples of the same material. Thus, for the above named solid waste constituents, the available absorptive capacity is given as equal to the moisture absorption capacity determined in the laboratory tests. The absorption capacities are summarized in Table IV-4. The moisture absorbed by grass, plant, leaves, shrubbery, tree prunings and food waste in the laboratory tests was less than the as-received (initial) moisture contents of these materials. This occurred because vegetation and food contain mostly water (up to 90 percent wet weight). In order to arrive at a meaningful estimate of the absorption capacity of waste vegetation and food in solid waste, it was assumed that the laboratory-determined moisture absorption plus an average as-received moisture content would equal the total moisture holding capacity of vegetation and food waste components. The total moisture absorption capacity of vegetation and food waste is given in Table IV-4. A minimum value of zero is given for food waste because it often enters the landfill in a saturated moisture condition.

The data may be applied to any landfill as illustrated in the following examples. If the composition of solid waste entering a landfill is known but the moisture content is unknown, the water absorption capability given in Table IV-4 can be used to estimate the available moisture absorption capacity. Applying this method to the composition of solid waste determined for Oceanside in April 1971 (given in Table IV-5), the maximum (180 percent dry weight) and minimum (60 percent dry weight) available absorption capacities were determined as shown in Figures IV-6 and IV-7. The data in Figures IV-6 and IV-7 assumed that no moisture was added to the solid waste; e.g. that the solid waste components were in their "natural" as-received condition. Rainfall and soaking with discarded household liquids would, of course, increase the as-received moisture content and decrease the available absorptive capacity.

If the moisture content of solid waste as-received at a landfill was known in addition to the dry weight solid waste composition, the data in Table IV-4 for total moisture holding capacity would be used to determine the available field moisture absorption capacity. Thus, in wet climates (>30 inches year) the available field capacity may be less than the water absorption and evaporation capability of a landfill.

4. Application of the Laboratory Test Data to Joint Sludge-Solid Waste Disposal at Oceanside. The available field moisture absorption capacity of solid waste as-received at the Oceanside landfill was calculated for the averaged annual solid waste composition and moisture content (see Table III-2, III-3). The results are presented in Table IV-6. The range of field absorptive capacities in Oceanside were estimated as from 60 to 178

TABLE IV-4
WATER ABSORPTION RANGES FOR SOLID WASTE COMPONENTS

Component	Moisture contents, percent dry weight					
	Water absorption capability			Total moisture holding capacity *		
	Maximum	Average	Minimum	Maximum	Average	Minimum
Newsprint +		290			290#	
Cardboard (solid and corrugated) +		170			170#	
Other miscellaneous paper	400		100	400#		100#
Lawn clippings (grass and leaves)	200		60	370		140
Shrubbery, tree prunings	100		10	250		0
Food waste (kitchen garbage)	100		0	300		0
Textiles (cloth of all types, rope)	300		100	300#		100#
Wood, plastic, glass, metal (all inorganics)		0			0	

* Calculated from water absorption plus initial moisture content in as-received samples. Initial moisture content from Figure VI-1 through VI-5.

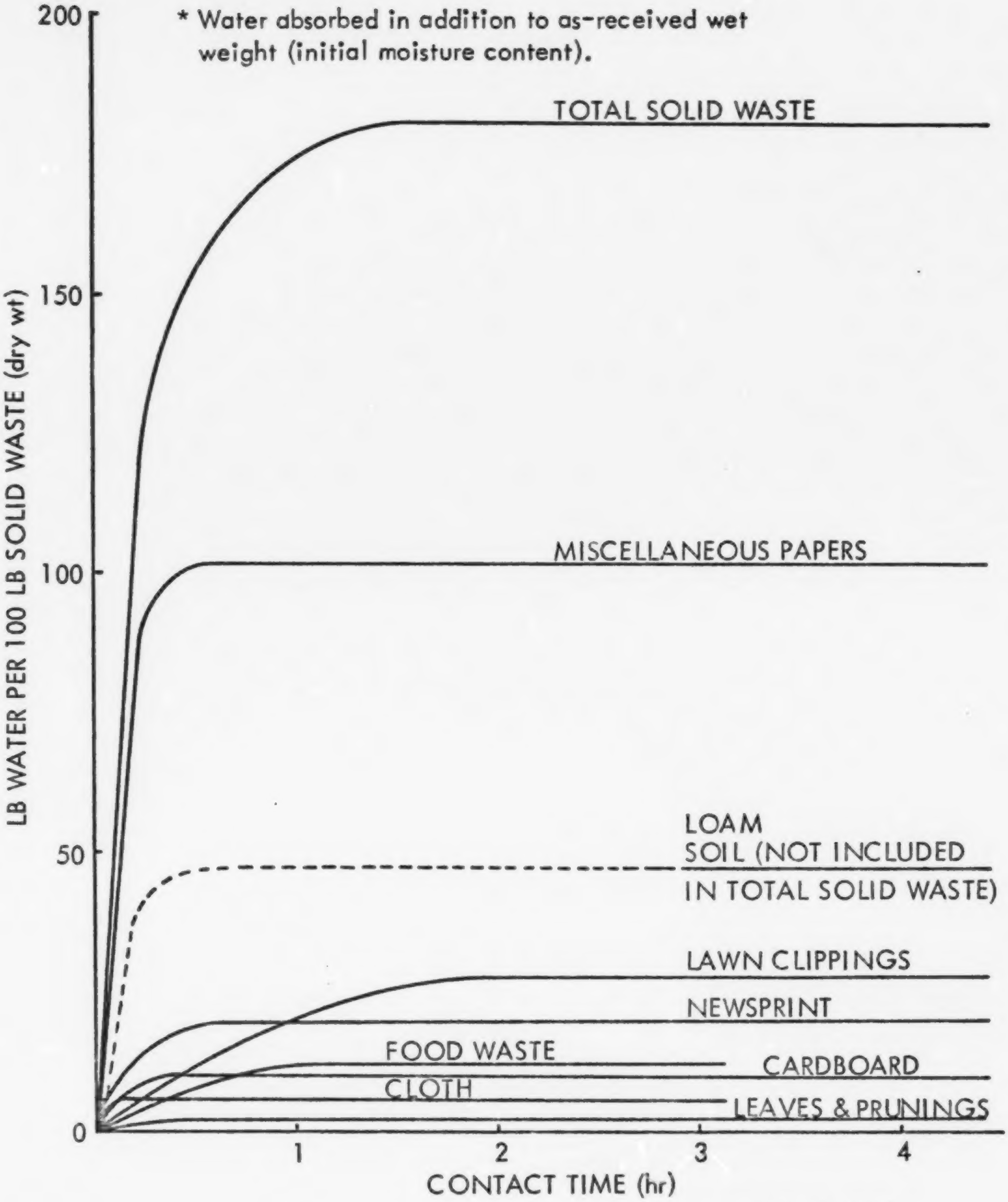
+ Sample variation was negligible.

Initial moisture contents as-received were less than 6 percent in the laboratory tests, therefore, they were considered negligible compared to the variation in moisture absorbed.

TABLE IV-5
CITY OF OCEANSIDE SOLID WASTE COMPOSITION
(PERCENT DRY WT BASIS)

Category of waste April 1971	One week average (percent dry wt)	Maximum daily variation (percent of one week avg)
Newsprint	6.73	+106
Cardboard	6.50	- 34
Miscellaneous paper	25.45	+ 84
Total paper	(38.68) *	+ 42
Food waste	11.62	+ 89
Glass & ceramics	11.97	- 52
Metals	6.40	- 19
Tree and shrub prunings	1.85	-100
Leaves	10.47	-100
Grass	2.40	+480
Total garden waste	(14.72) *	+100
Textiles	1.79	+ 45
Tires	3.76	-100
Foam plastic & rubber	0.24	+138
Other rubber & plastic	2.74	+ 38
Total rubber & plastic	(6.74) *	+300
Wood	1.69	+131
Dirt, sand, ash	0.44	+ 43
Concrete and rock	0.10	+480
Other (unclassifiable)	5.82	+ 75
Total	100.0	-

* Sub-totals; not included in total.



* Water absorbed in addition to as-received wet weight (initial moisture content).

FIGURE IV-6

MAXIMUM ABSORPTION OF WATER IN MUNICIPAL REFUSE (EQUIVALENT DATA ON SOIL (LOAM) PRESENTED FOR COMPARISON)

CITY OF OCEANSIDE/E.P.A.

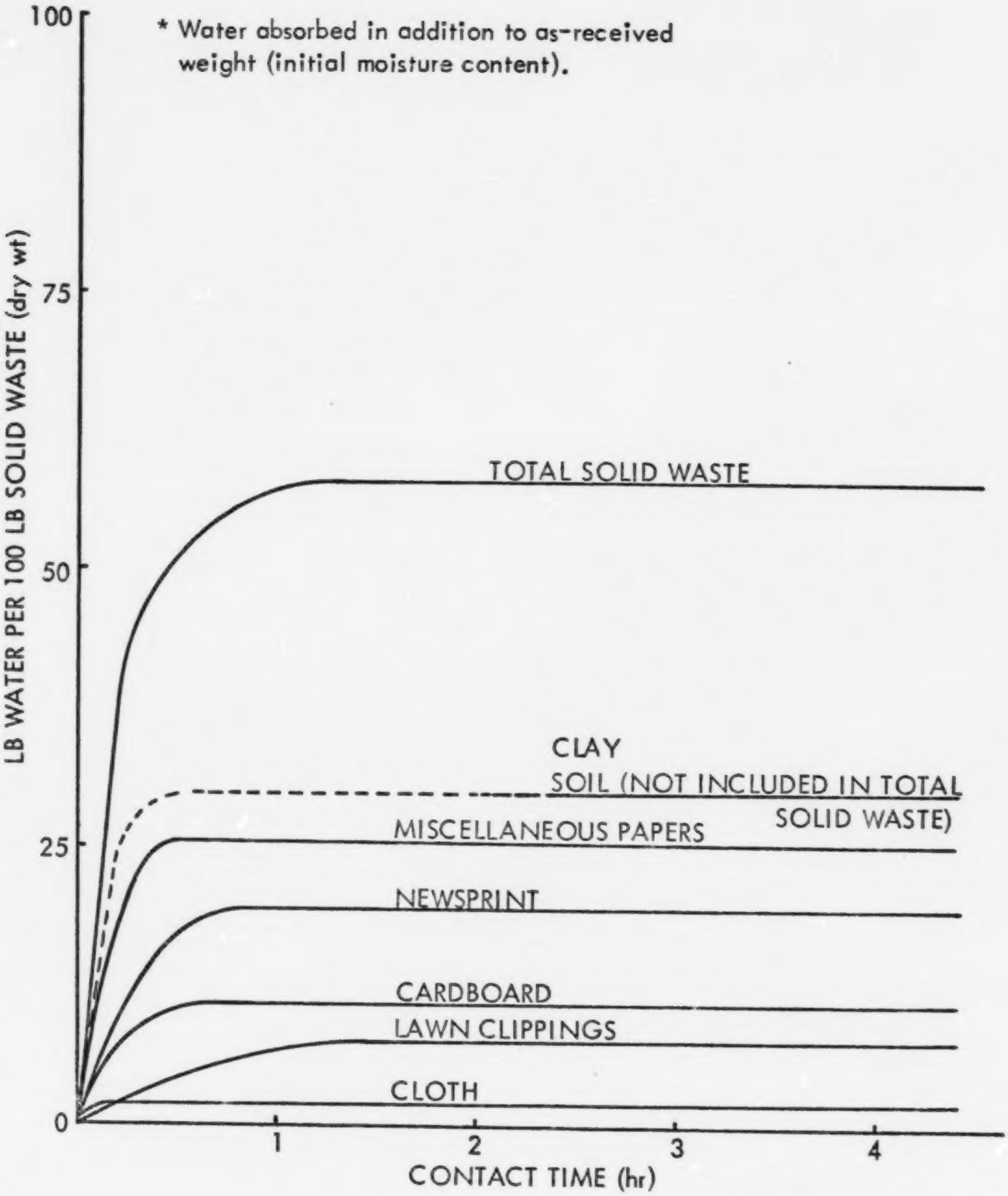


FIGURE IV-7
MINIMUM ABSORPTION OF WATER
IN MUNICIPAL REFUSE (EQUIVALENT DATA
FOR SOIL (CLAY) PRESENTED FOR COMPARISON)

percent dry weight basis. The close agreement between the absorptive capacity data in Table IV-6 (60 to 178 percent) and Figures IV-6 and IV-7 (60 to 180 percent) is attributed to the Oceanside as-received solid waste moisture content consisting of primarily natural moisture in the solid waste components. There was little rainfall during the periods when the Oceanside solid waste samples were taken; thus the only source of moisture would be from discarded household waste liquids and normal content, as received.

5. Summary of Moisture Absorption Capacity. The composite curves in Figures IV-6 and IV-7 (e.g., Total Solid Waste) indicate the ultimate saturation values that may be reached if the solid waste layers and associated cover soil layers are sufficiently compacted so that applied fluids remain in contact with the waste mass for approximately one hour before excess water drains through to lower strata. If the weight ratio of cover and admixed soil to waste were known, the ultimate absorption capacity of the soil would be included with those of waste components in estimating the total capacity for an operating landfill.

The data in Figures IV-6 and IV-7 and Table IV-6 indicate that 0.6 to 1.8 lb of liquid could be added for every 1.0 lb of dry weight solid waste before complete saturation is reached. As will be discussed in Chapter VI, subsequent larger-scale water absorption studies ("drum" tests), conducted in April 1971 Oceanside-type refuse composition indicated an average saturation value of 1.74 lb of liquid per 1.0 lb of dry weight solid waste. For the 13 drums tested , the spread in lb per 1.0 lb dry weight was from 0.57 to 2.72, with only three points outside the 1.0-2.2 range and eight points in the 1.0-1.9 range.

The City of Oceanside produces approximately 0.6 lb of sludge for every 1.00 lb dry weight of municipal refuse. Theoretically, therefore, the solid wastes generated by the City should have adequate capacity to absorb all the water in the liquid sludge. This was verified in a number of field tests at the Oceanside landfill in which sewage sludge was applied to solid waste at a rate of 0.35-0.6 lb of sludge per 1.0 lb of solid waste wet weight. A total of 35 applications were made (one day per week for 35 weeks over a ten-month period). No leachate that could be attributed to landfill moisture saturation (field capacity) was observed during this period. In cases where minor sludge runoff occurred, it was the result of an inappropriate spreading technique and the runoff was absorbed into the fill cover.

The above data indicate that the water retention capacity of Oceanside municipal solid waste falls above the upper half of the range predicted by the sum of the specified absorptivities of its major identifiable components. The increase in retention capacity may be attributed to entrainment of some fluid between particles (in addition to the amount absorbed). The drum having the lowest absorptivity (0.57 lb liquid per 1.0 lb solid waste) received very thin (watery) septic tank pumpings. In this particular test, there were also indications that the applied fluid percolated rapidly through the solid waste and, hence, there was little absorption time which reduced the amount absorbed. The high drum absorptivity reading (2.72 lb per 1.0 lb drum solid waste) occurred with the thickest sewage sludge. Due to its relatively high viscosity, a thick sludge cannot percolate through the solid waste particles very rapidly,and hence a higher absorptivity

TABLE IV-6
PREDICTED RANGE OF ABSORPTIVE CAPACITY OF MUNICIPAL REFUSE AS RECEIVED AT OCEANSIDE LANDFILL

Component	Total moisture holding capacity as determined in laboratory tests*		Available field absorption capacity of waste components +		Average composition # (percent)	Field absorptive capacity**	
	Maximum	Minimum	Maximum	Minimum		Maximum	Minimum
Newsprint	290		262		7.2	19	
Cardboard	170		146		8.3	12	
Miscellaneous paper	400	100	397	97	23.6	94	23
Leaves and grass	370	140	312	92	3.8	12	4
Prunings	250	10	207	0	6.3	13	0
Garbage (food waste)	300	0	229	0	9.2	21	0
Textiles	300	100	284	84	2.3	7	2
Non-absorbents++	0	0	0	0	39.3	0	0
Total					100.0	178	60

* Oven-dried samples, from Table IV-4, percent dry wt basis.

+ The absorptive capacities determined in laboratory tests reduced by the measured moisture contents from Oceanside waste samples, percent dry wt basis.

# Average of year's (four quarters) composition of collected refuse arriving at Oceanside municipal landfill site.

** Pounds water per 100 pounds of average mixed refuse as received at the landfill; derived from product of available absorptive capacity and average composition for each component.

++ Includes wood (absorption very slow), foam plastic (insignificant quantity), and dirt, sand, and ashes (which entrain but do not absorb).

was obtained. The aforementioned water-absorption to solid waste weight ratios indicate that the retention capacity of a municipal solid waste can be predicted fairly accurately when the composition of the solid waste and the water-absorption capacities of its components are known. The required data can be generated by field sampling and laboratory tests such as those used in this study.

V. SEPTIC TANK PUMPINGS EVALUATION

A. Purpose and Scope

A literature survey and pilot test drum evaluation of septic tank pumpings admixed with solid wastes was undertaken. Since septic tank pumpings consist of raw or partially stored sewage, they are known to contain pathogenic organisms. The study scope was proposed by the E.P.A. Project Officer in lieu of demonstration landfill tests to evaluate the potential hazards that might be created if septic tank pumpings were disposed into the Oceanside sanitary landfill. The demonstration full scale tests were avoided because of the limited available septic tank pumpings and also concern about the possible health hazards and noxious odors. The results of this evaluation provide the basis for determining if landfill disposal of septic tank pumpings will be field-tested during Year 03 of this demonstration grant.

B. Pathogenic Organisms in Septic Tank Pumpings

1. Types of Organisms. The types of pathogenic organisms associated with municipal sewage, sewage sludge and septic tank pumpings are identical. Septic tank pumpings are basically raw or partially digested fecal waste and are similar to raw sewage in pathogenic organism types and populations. However, well digested treatment plant sludges contain far fewer pathogenic organisms than the "raw" sewage and septic tank pumpings.

The pathogens in human fecal waste and raw sewage have been well-documented. In a review of the literature, Hanks[4] has identified the disease agents associated with fecal waste including septic tank pumpings as follows:

a. Bacterial Infections. Typhoid fever, paratyphoid fevers A and B, cholera, and shigellosis are enteric bacterial diseases in man. The pathogenicity of E. coli organisms is not entirely clear.

The viability of these bacteria in the environment is summarized as follows. Shigella can remain viable in tap water for as long as 6 months and in sea water for 2 to 5 months. Shigella can be destroyed by pasteurization and chlorination. The viability of Salmonella typhi is from 2 to 3 weeks in ground water, 1 to 2 months for fecal matter in privies, and at least 3 months in ice or snow. E. coli, Salmonella and Shigella can be killed by pasteurization at 66C for 30 minutes or by chlorination with 0.5 to 1.0 mg/l concentrations.[5]

b. Viruses. The major viruses commonly found in human excrement are adeno, reo, poliomyelitis, coxsackie and infectious hepatitis. Poliomyelitus and coxsackie are viable in sewage and septic tank pumpings.

Most viruses may be destroyed by extreme temperatures greater than 100°C. Recently, Shell and Boyd[36] determined in composting dewatered sewage sludge that poliovirus type 1 was destroyed by temperatures as low as 50°C (122°F). Chlorination can prevent the spread of infectious hepatitis, and most adinoviruses and enteroviruses are destroyed after remaining a period of 10 minutes in contact with residual chlorine levels of 0.3 to 0.5 mg/l.

c. Protozoal Infections. The most significant protozoa disease agent is Entamoeba histolytica which is the only specie found in the United States. Cysts of Entamoeba histolytica are destroyed by dessication, sunlight and heat. Thus, it would appear that protozoa would not likely survive in the landfill environment.

d. Helminthiasis. This type of pathogen consists of worm infestations of human fecal origin. The most common are the tapeworms including Diphyllobothrium latum (fish tapeworm), Taenia saginata (beef tapeworm), Taenia solium (pork tapeworm) and Enterolines vermiculoris (pinworm). Also included are the human roundworm (Ascaris lumbriocoides), the whipworm (Trichuris trichiura), and the human hookworms (Necator americanus and Ancylostoma duodinale).

2. Vectors. Either direct or indirect contact with infected fecal matter must occur before an infection or disease can result. The four major disease routes are vector-borne, soil-borne, direct contact, and waterborne; air-borne is a secondary pathway.

A major mode of disease transmission is by direct contact with biological vectors (houseflies, cockroaches and domestic mosquitoes). The diseases transmitted by these vectors are amoebic dysentery, cholera, coxsackie (disease), infectious hepatitis, poliomyelitis, shigellosis, typhoid and paratyphoid fevers, and worm (helminth) infections.

Disease transmission routes related to septic tank pumpings disposal into a landfill would include: direct contact during disposal or while working solid waste; transmission by water (surface and ground water contamination from runoff and leachate); contact by vectors such as houseflies foraging in infected wastes; and by contamination of other foraging wildlife (birds, dogs, rats, etc.) that could come into contact with humans. The methods of transmitting coxsackie and polio viruses are not well-defined; viruses have been found in water and in flies having access to infected feces.[4] Also there is data suggesting polio virus can survive in contaminated water, i.e. the disease may be waterborne. Infectious hepatitis is transferred chiefly through direct contact or fecal contamination of water supplies. There is evidence that municipal sewage treatment plants do not effectively remove the hepatitis virus. This is substantiated by higher hepatitis morbidity in communities where treated sewage is discharged into streams or estuaries. Hazards may be expected to hold for septic tank pumpings.

The primary route of typhoid propogation is the human typhoid carrier. Typhoid infected fecal waste has been associated with the direct contamination of well water by septic tanks and privies as well as other water supplies, and milk or food not properly protected.

Worm infestations of human feces are common. Sewage sludges have been found to contain eggs of pathogenic helminths. The use of untreated (raw) sewage sludge as soil conditioners for food crops is not recommended in order to protect against worm infestations through direct contact.[6].

3. Pathogenic Characteristics of Septic Tank Pumpings and Sewage Sludge. Concentrations of pathogenic organisms in septic tank pumpings would be about as great as in raw sewage due to: the continual daily addition and admixture of fresh raw sewage; and the low degree of biological treatment in comparison to sewage plant sludge treatment and digestion. Laboratory analyses have shown that between 90 and 98 percent of coxsackie and polio virus are removed by the activated sludge process. The primary sedimentation sewage treatment process which is similar to the septic tank process is relatively ineffective in virus removal.[7] The same rate of removal noted above for virus can also be achieved for pathogenic bacteria by the activated sludge process.

Chlorination may be used for disinfection to produce virus - and bacteria-free sewage sludge and septic tank pumpings. Long contact periods with high chlorine residual concentrations are necessary to insure destruction of pathogens.[8] Heat-dried sludge has been considered to be free from disease agents.[9, 10]

C. Potential Pathogenic Effects of Disposing Septic Tank Pumpings Into Sanitary Landfills.

1. Viability and Survival of Pathogens in Landfills. As discussed above, the pathogenic bacteria can be killed by pasteurization at 66 C for 30 minutes; virus destruction requires exposure to temperatures of 50 C or greater. Gotaas[11] and Golueke and Gotaas[12] have shown that a temperature of 60 C for one hour should kill all non-spore-bearing pathogens. The upper range of temperatures generally found in sanitary landfills with and without sewage sludge admixture are 45 C to 65 C. The higher end of the landfill temperature range in combination with the greatly increased time of exposure to the high landfill temperatures appears to be sufficient to destroy bacteria and virus.

Samples taken after six months at four-and twelve-foot depths in the three Oceanside field test cells (one of which received raw primary sludge) were analyzed for fecal coliform, fecal streptococci and Pseudomonas aeruginosa; at depths of 12 feet (see Table VII-21) none of these fecal bacteria were detected. The viability and survival period for viruses in the landfill environment is not known. It appears, however, that anaerobic landfill temperatures will destroy some viruses. Virus generally require host animal cells for survival. Since biodegradation of food (including animal cells) is fairly rapid in landfills, the survival of virus may be limited. However, no definitive statement is possible on virus viability in landfills until studies are made to determine the potential health hazards.

An average of 5 to 10 million bacteria and fungi, and 740,000 coliform bacteria have each been measured in one gram of solid waste.[13] Leachate analyses from other studies have shown concentrations as high as 9,500 coliforms per ml,[14] and coliform counts (MPN) up to 100,000 per mg, have been measured experimentally.[15]

E. coli in oven-dry fresh solid waste has been found in densities over 5,000 MPN organisms per gram. This value was reduced to 0 to 100 MPN organisms per gram after a storage period of three years. Corresponding values for Streptococcus faecalis were 2,500 and 0 to 60 organisms per gram of dry refuse, respectively.[16] Thus, solid waste as well as septic tank pumpings are a source of pathogenic organisms, particularly during the material handling and landfilling process.

2. Pathogen Transmission. Ralph Stone and Company, Inc. found in pilot test drums receiving septic tank pumpings that the pumpings settled out to form distinct separable liquid and solid phases. Also the spread septic tank liquid behaved like water and rapidly penetrated into the solid waste interstices leaving a layer of solids on the solid waste surface. The rapid liquid percolation produced instant drainage. The raw primary sewage sludge applied to field test Cell 1 also produced immediate leachate drainage; Cell 1 was the only one of three test cells to have minor leachate drainage (until heavy rainfall when some short circuiting occurred). It was noted that the odor, appearance, consistency, viscosity, and low total solids content (2.5%) of the raw primary sludge disposed into Cell 1 were similar to septic tank pumpings applied to the pilot test Drums 3 and 16 (compare Tables VI-4 and VII-4). Thus, if septic tank pumpings were disposed into a sanitary landfill, leachate would more readily occur unless carefully controlled disposal techniques were used.

Analyses made of Cell 1 leachate indicated an E. coli count of over 3,000 MPN in a sample taken eight days after Cell 1 filling was completed. On leachate samples taken after 15 days E. coli was 300 MPN, and after 28 days E. Coli counts were less than 3 MPN.

It is apparent from the pilot test drum and field test Cell 1 data that a potential hazard could exist from septic tank pumpings disposal into a sanitary landfill unless adequate runoff and leachate control facilities are constructed.

3. Leachate Contamination of Ground and Surface Waters. Most pathogens die naturally as they are filtered by the soil before or after reaching ground water systems. E. coli has been shown to be viable for 31 months in polluted ground water.[17] One study shows that some viruses are more resistant to chlorination than E. coli since more chlorine is needed to kill these viruses than similar populations of E. coli.[18]

While pathogenic organisms may be present in runoff and leachate, a public health hazard does not necessarily exist. Soils have the capability of filtering out pathogens in leachate, and it has been reported that coliforms are seldom found below the four-foot level, and never below seven feet, even in highly permeable soils.[19] If bacteria happens to penetrate the ground water system, it is reported that the bacteria will not survive more than 50 yards in the direction of ground water flow.[20]

One study has shown that shallow landfills may leach the bulk of pollution in a relatively short period of time and thereby exceed the dilution capacity of the receiving ground waters.[21] The rate of bio-oxidation with septic tank pumpings admixed into solid waste in pilot test drums appeared to be less than for sludge admixed waste and watered solid waste. A lower bio-oxidation rate may reduce the strength of leachates during the first six months after disposal while most pathogens are likely to be alive. The data on Drums 3 and 16 (septic tank pumpings admixed) show settlements at the low end of the range of pilot test drum settlements (50 to 53 percent), lower peak BOD_5 values (about 1,000 mg/l) than all but two other drums, and low percentages of CO_2 (Drum 16) and negligible CH_4 (Drum 3) (see Appendix D and Figures VI-7 to VI-11).

4. Odors and Fly Problems. A major nuisance accompanying septic tank pumpings (and also anaerobically digested sludge) is odors. Foul septic odors can annoy residents near landfills. Odors attract flies which contact wastes resulting in an increased risk of disease spread by fly transmission. Daily covering of the landfill working face can control fly and odor problems.[22]

Fly problems are usually only associated with open dumps or inadequately covered landfills. Flies may migrate up to five miles from an open dump imposing a disease threat on residents within the five-mile radius. Disease transmission via rodents and other biological vectors make open dumps unacceptable from a public health standpoint. A properly maintained sanitary landfill eliminates rodents and flies by removing their food and shelter with a compacted soil cover. Six inches or more of compacted earth will prevent the emergence of flies covered by the soil; in contrast, flies can emerge through five feet of uncompacted soil.

D. Existing Practices for Disposal of Septic Tank Pumpings Into Sanitary Landfills

At present some communities have reservations about discharging septic sludge directly into landfills and have passed legislation prohibiting the processing of untreated sludges at landfills.[23] A 1968 survey of California disposal sites showed that 37 percent of the open dumps and 44 percent of the sanitary landfills were operating under ordinances banning sewage treatment residues.[24]

The 1971 national survey completed by Ralph Stone and Company, Inc. (see Section II of this report) indicated disposal of septic tank and liquid sewage sludges was prohibited by 70 percent of responding landfills. Respondents cited odors and pathogenic organisms as major hazards.

E. Management of Landfill Hazards from Septic Tank Pumpings Disposal

The public health hazard from septic tank sludge disposal can be minimized if a properly located and operated landfill is employed. Landfills should generally be sloped to provide runoff away from surface waters and located to avoid local water supply contamination. Mixing liquid sludge with dried sludge can also inhibit the leaching process.[23] Similarly admixing liquid sludge with solid waste can prevent leaching. Of course a fill area may be eventually saturated by sufficient rain or irrigated water to cause leaching. Thus, an impermeable seal or landfill underdrain system, runoff and storm drain facilities are necessary to control and collect leachate to avoid public health hazards. The collected leachate may then be treated on-site (by oxidation) or returned to nearby sewers if available.

The ratio of septic tank pumpings to solid waste may be reduced below the minimum expected moisture absorption ratio of the local solid waste (0.6 for the City of Oceanside) to increase the probability of complete absorption without runoff or leaching. Other techniques include reducing the slope of the landfill working face, constructing soil dikes at the toe of the working face and uniform spreading of septic tank pumpings onto the surface of solid waste fill. Continuous fresh earth cover of the liquid pumpings, admixed to the solid waste must be carefully applied with a minimum daily final cover of 6 in. of clean compacted earth to control odor, pathogen and vector problems.

F. Summary

Given the results of the previous discussions, it appears that the major identifiable health hazard associated with disposal of septic tank pumpings into a sanitary landfill will occur during the disposal operation. This will result due to the following: existing pathogenic organisms will be at their peak, virulent populations; the fresh septic tank pumpings will be exposed and, therefore, readily accessible to flies, other insects, birds and vermin such as rats; the landfill operating personnel will be in closest contact with the septic tank pumpings; and the potential for runoff due to short-circuiting through landfilled solid waste interstitial passages will exist. The potential health hazards will decrease and eventually become negligible with increasing time after disposal. If the landfill operating techniques, protective clothing, runoff and leachate control facilities described in the preceding section are utilized, landfill disposal of septic tank pumpings could be feasible.

VI. PILOT-SCALE SIMULATION OF LANDFILL CONDITIONS

A. Purpose and Scope

The objectives of the pilot tests were to simulate, under controlled conditions, the behavior of a representative mass of municipal solid waste in a landfill to which liquid sewage sludge and water are applied to: a) determine the quantity of sewage sludge, water, and septic tank pumpings that can be absorbed by solid waste, b) assess the environmental effects that might result from such sludge disposal, and c) evaluate the potential for groundwater pollution from leachates.

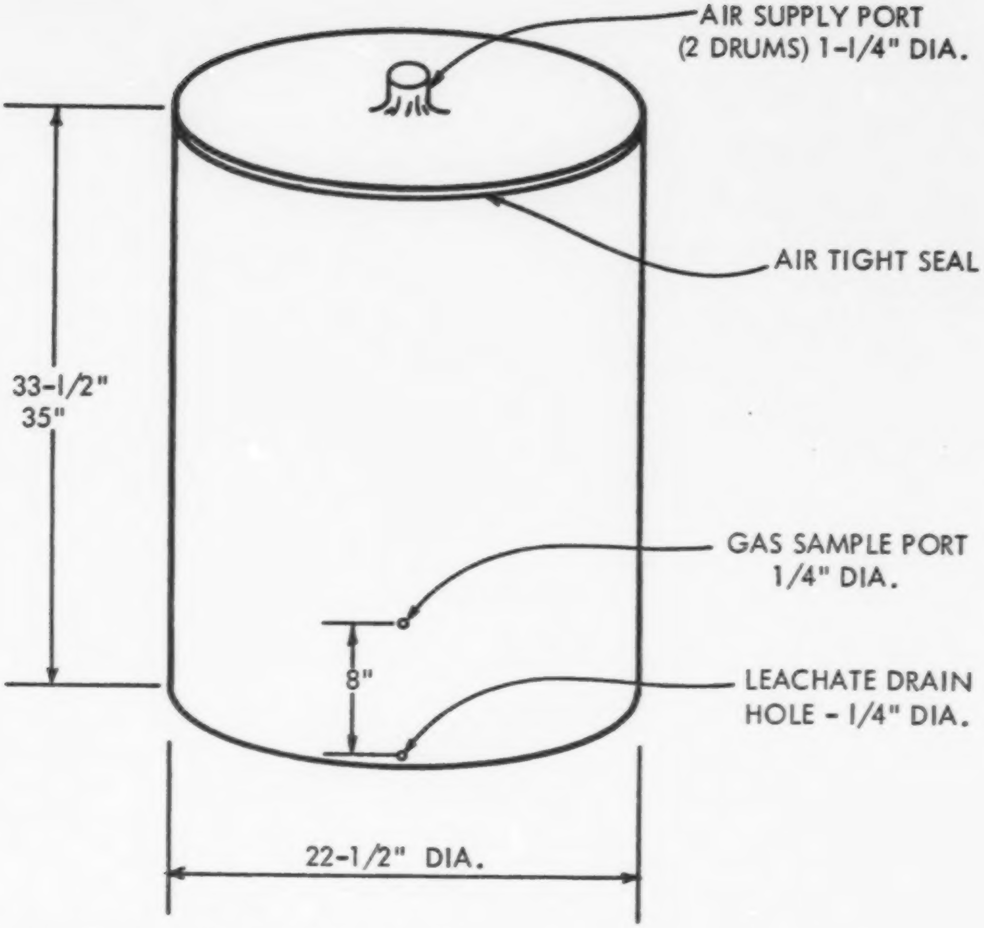
The control parameters held constant were the amount and composition of solid waste and the degree of compaction. The variable parameters were the kind, amount, and sequence of liquids applied, and the sequence of compaction. The measured variables of primary interest were the time-variation of BOD_5 value of the leachates and the rate of subsidence. Other measured variables were the rate of leachate emission, temperature, gas composition, and chemical properties of the leachates, including conductivity, pH, turbidity, and total nitrogen. Qualitative observations were made for odor, color of leachates, apparent degree of decomposition of solid wastes, population and types of insects, and microorganism growths.

Based on the premise that the tests adequately simulated the operation of a landfill, the resulting data provided an indication of the results to be expected from the joint solid waste-sludge landfill disposal operation.

B. Description of the Study

1. Pilot Test Facilities Configuration. The pilot test facilities were installed at the Los Angeles, California, home office of the Consultant, Ralph Stone and Company, Inc. (in regard to temperature and rainfall, the weather in Los Angeles is very similar to that in Oceanside). The pilot test facilities consisted of eighteen 55-gallon drums as illustrated in Figure VI-1. Seven of the drums were 35 in. in height, whereas the remaining eleven drums were 33½ in. in height. Each drum was provided with a leachate drain and a gas sample port. Two drums were aerated intermittently through an air supply port located on the top of the drums (see Figure VI-1). The leachate drain hole in each aerated drum remained open throughout the test period to provide an air exit after passage through the solid waste. Anaerobic conditions were attempted in the remaining 16 drums by providing a polyethylene air barrier and sealing the drum lids. (See Photograph VI-1c and Figure VI-1.)

2. Solid Waste Characteristics. The drums were filled with solid waste of a composition approximating that of Oceanside, California (as established by hand sorting of statistically valid samples). The actual composition of the wastes placed


AIR SUPPLY PORT
(2 DRUMS) 1-1/4" DIA.
AIR TIGHT SEAL
33-1/2"
35"
GAS SAMPLE PORT
1/4" DIA.
8"
LEACHATE DRAIN
HOLE - 1/4" DIA.
22-1/2" DIA.

NOTE: DRUMS OF TWO HEIGHTS WERE USED - 7 DRUMS AT 35", 11 AT 33-1/2" (STEEL DRUMS WERE ASPHALT COATED)

CITY OF OCEANSIDE/E.P.A.

FIGURE VI-1
PILOT TEST DRUM
CONFIGURATION

a. PILOT DRUM FILLED WITH SOLID WASTE.

b. ADMIXING SEWAGE SLUDGE INTO PILOT DRUM.

c. POLYETHYLENE MEMBRANE AIR (OXYGEN) BARRIER TO SIMULATE ANAEROBIC LANDFILL CONDITIONS.

CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VI-1

PILOT TEST DRUMS

in each drum, plus the Oceanside standard sample composition, is given in Table VI-1. Of course, there was minor variance within each of the categories of Table VI-1 of the drum materials filled on different dates. Efforts were made, however, to insure maximum random conformity within each waste category from the variety of materials available at the time. (See Photograph VI-1a.)

The weighed quantities of each component were placed in each drum by hand, taking reasonable care to avoid excessive concentrations of any one component in a single location. No effort was made to achieve completely random mixing, such as by tumbling in a large container. Instead, it was attempted to duplicate visually the appearance of waste materials lying in a landfill.

3. Filling and Compaction Procedures. The purpose of the first test (Drum No. 1) was to establish the maximum amount of sludge that can be absorbed by a known quantity and composition of solid waste. In the pilot plant the sequence of solid waste and sludge additions, mixing, and compacting was intended to simulate landfill operating conditions. Half of the total charge of 100 lb of solid waste was first placed in the drum, compacted, and then sludge was added. The mass was then stirred several times to promote complete admixture, and compacted a second time. Small amounts (about 10 lbs) of solid waste was applied daily until 100 lbs was in the test drum. Liquid sewage sludge was admixed daily with the solid waste, and added after 10 lbs of solid waste was in the drum until leachate started to drip from the bottom drain, at which time it was assumed that saturation conditions were reached. Due to the high viscosity of applied sludge and careful arrangement of solid waste to prevent channeling, it was assumed that the leachate represented the excess liquid sludge that percolated through the saturated mass of refuse. Due to the method of filling (compaction), Drum No. 1 initially contained 100 lb (wet weight) of solid waste at about 22 lb/cu ft wet density (594 lb/cu yd). All other drums contained 80 lb of solid waste, each at initial wet densities ranging from 12.4 to 22.1 lb/cu ft (see Table VI-2). (See Photograph VI-1b.)

The initial compaction for Drums 2 through 5 consisted of dropping a 200-lb weight two times, from approximately 1 ft above the solid waste surface. Drums 6 through 18 were subjected to continuous manual tamping of solid waste layers with a shovel during packing. This resulted in a more thorough and uniform compaction throughout the waste charge. The difference in initial compaction procedures simulated two sets of landfill conditions: a) compaction of each fill layer (Drums 6-18); and b) compaction of a complete fill (Drums 2-5). The variation in initial density of waste material in the drums is given in Table VI-2.

4. Liquid Application. Liquids were applied to all but one (Drum No. 18) of the 18 drums as shown in Table VI-3. Raw sludge, digested primary and activated sludges, mixed sludge, septic tank pumpings, and water were used in these tests to achieve saturation during either primary or secondary application as indicated in Table VI-3. The term "Primary Application" in Table VI-3 refers to an initial phase of the liquid addition, in which sludge was poured into the newly filled drums of solid waste in the amounts indicated. The ratio of 0.61 lb of liquid sludge per pound of solid waste, wet wt, used in most drums reflects the higher ratio of sewage sludge

TABLE VI-1
COMPOSITION OF SOLID WASTE IN TEST DRUMS

Constituent	Composition (percent wet wt) Drum number 1	2	3	4	5	6 through 18	Oceanside waste standard*
Newsprint	13.1	8.8	11.3	12.3	12.9	7.5	6.73
Cardboard	5.4	2.5	0.1	3.9	5.1	7.5	6.50
Misc. paper	22.8	21.3	19.7	23.8	18.4	25.0	25.45
Total paper+	41.3	32.6	31.1	40.0	36.4	40.0	38.68
Prunings	21.0	2.5	4.0	4.5	4.2	1.9	1.85
Leaves & grass	13.4	29.8	21.3	22.5	28.2	13.1	12.87
Total yard waste+	34.4	32.3	25.3	27.0	32.4	15.0	14.72
Food waste	0	18.8	12.5	8.8	9.1	12.5	11.62
Cans & bottles	0	16.3	16.7	9.6	9.2	18.8	18.37
Wood	1.9	2.5	2.5	4.7	3.5	2.5	1.69
Cloth	0.5	0	3.2	1.8	0	2.5	1.79
Gravel	11.3	0	0	0	Trace	2.5	0.10
Film or foam plastic#	Trace	Trace	Trace	Trace	Trace	Trace	6.73
Miscellaneous**	10.6	7.5	8.7	8.1	9.4	6.2	6.30
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

---

*Typical municipal solid waste of Oceanside, California, based on April 1971 hand sorting of statistically valid representative samples.

+Not included in totals.

#Visually conspicuous, but of insignificant weight.

**Mostly dirt in test drums, and unclassifiables in standard.

TABLE VI-2
INITIAL DENSITY OF SOLID WASTE IN TEST DRUMS*

Drum number	Wet wt of solid waste (lb)	Initial wet density (lb/cu ft)	Initial wet density (lb/cu yd)
1	100	22.0	594
2	80	13.5	365
3	"	14.6	394
4	"	13.0	351
5	"	14.1	381
6	"	15.6	421
7	"	12.4	335
8	"	14.1	381
9	"	20.3	548
10	"	17.4	470
11	"	15.2	410
12	"	12.8	346
13	"	14.9	402
14	"	20.3	548
15	"	16.6	448
16	"	22.1	597
17	"	16.6	448
18	"	15.9	429

*Before admixture of liquid.

TABLE VI-3
APPLICATION OF SLUDGE AND WATER TO TEST DRUMS

Drum no.	Initial application	Second application	
		Sludge	Water
1	Saturated with mixed municipal sludges, digested activated sludge (La Salina) and digested primary sludge (San Luis Rey).		X
2	Water only.	La Salina	
3	Domestic septic tank pumpings. Ratio *: 0.61.		X
4	Dry control with single water application.	Left dry	
5	Mixed digested sludges (La Salina, San Luis Rey). Ratio: 0.61.	La Salina	
6	Digested activated sludge. (La Salina). Ratio: 0.61.	La Salina	
7	Digested activated sludge. (La Salina) Ratio: 0.61.		X
8	Saturated with thinner digested activated sludge (La Salina).	La Salina	
9	Saturated with thicker digested activated sludge (La Salina).		X
10	Raw primary sludge (San Luis Rey). Ratio: 0.61.	San Luis Rey (raw)	
11	Raw primary sludge (San Luis Rey). Ratio: 0.61.		X
12	Digested primary sludge (San Luis Rey) Ratio: 0.61.	San Luis Rey (digested)	

Cont'd

TABLE VI-3 (CONT.)

Drum no.	Initial application	Second Application	
		Sludge	Water
13	Digested primary sludge (San Luis Rey). Ratio: 0.61.		X
14	Digested activated sludge; drum aerated (La Salina). Ratio: 0.61.	La Salina	
15	Digested activated sludge; drum aerated (La Salina) Ratio: 0.61.		X
16	Domestic septic tank pumpings Ratio: 0.61.	Septic tank pumpings	
17	Water only		X
18	Dry control	Left dry	

* Ratio = lb liquid per lb solid waste in each drum.

to municipal solid waste generated by the community of Oceanside over recent years. These drums thus simulate the absorptive capacity that would be required for sludge disposal for the community of Oceanside.

Drums in which the solid waste was "saturated" with liquid sludge simulate sanitary landfills of comparable solids composition used at their maximum capacity for sludge absorption. "Saturation" refers to the maximum amount of liquid (sludge or water) that the contents of the drums could absorb without producing leachate, as evidenced by prolonged slow dripping from the leachate drain hole in the bottom. In several cases, it was observed that rapid "run-through" (run-off) of applied liquid occurred due to short-circuiting through voids and channeling along the drum walls prior to reaching the 0.61 ratio or saturation. In these cases, the effluent was caught and poured back in the drum until the leakage ceased. In cases where the leachate flow decreased to a slow drip that lasted for over 16 hours, the contents were assumed to be saturated.

During the "primary water application" program, Drums 1, 8 and 9 were selected for saturation tests with liquid sewage sludge. Drum 1 reached saturation in six days, Drum 8 in nine days and Drum 9 in ten days.

After "primary water applications," initial determinations were made of subsidence under compaction, quality of leachate (where leachates were formed), temperature rise, and attractiveness to flies and other vectors. A program of "secondary water applications" was then started. Secondary liquid sludge and water applications were made to the drums at a rate of 1 gal per day, 5 days per week, until each pilot drum was saturated, after which only water was applied to each drum at approximately the same rate for a total of 59 working days. The total quantity of water added (59 gallons per drum) is equivalent to 36 in. of cumulative rainfall on the surface area of the test drums. An annual rainfall of 36 in. is equal to a maximum rainfall condition for the City of Oceanside. However, since one year of "rainfall" was applied during a period of only 59 days, the experiment may be regarded as a simulation of a very wet period.

Initially, the addition of water at a rate of 1 gal/day consisted of actual addition of 1 gal of water to each drum, except 4 and 18 (dry controls), once every working day. This procedure, however, was found somewhat time-consuming and hence was modified to involve addition of 2 or 3 gallons of water at one time every 2 or 3 days. Thus, an "average" rate of 1 gal/day was maintained throughout the period of "heavy rainfall" simulation.

To simulate an intermediate rainfall, the rate of water addition was later reduced to three gallons once every week for a total quantity of 21.6 inches. The rate of water addition was continued until January 1972, since which time the rate has been further reduced to simulate light rainfall, 3 gal once a month for a total of about 21.6 in. of rainfall per year.

Since the contents of most of the drums were at or near saturation at all times (generally as a result of secondary applications), the liquid would drip continuously when the drain holes were left open. This created some anaerobic odor nuisance in the immediate vicinity, as well as major losses of leachate due to overflowing and evaporation from leachate collection pans. Thus, about 60 days after beginning of the study, the leachate drain holes were kept corked, except when leachates were collected. As a result, most of the drums accumulated small amounts of free leachate in their bottoms.

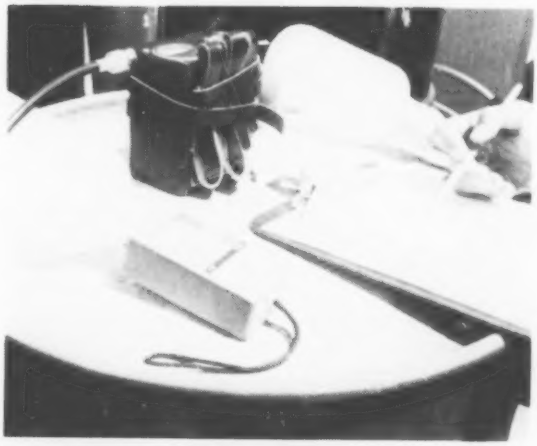
5. Forced Aeration Conditions. Two of the test drums, 14 and 15, were provided with forced aeration from a blower. The hoses entered via connections through the lids of the drums (see Figure VI-1); these lids were provided with gaskets in insure an airtight seal. Unlike the other drums, the gas sampling holes on these two drums were left uncorked, allowing the air from the blower to percolate downward through the solid waste and out the holes. The leachate drains were initially kept corked, as with the other drums, and then opened to allow the air to flow through the bottom of the waste charge. The blower was activated by a timer, which operated it for 5 min each hour, at a divided flow providing approximately 5 SCFM to each drum. This aeration sequence was believed adequate to prevent any significant accumulation of carbon dioxide or methane, thus maintaining aerobic conditions, while not causing excessive drying.

6. Monitoring Program. The following is a brief description of sample collection and monitoring procedures employed in connection with the drum tests.

a. Leachate Collection and Analysis. In general, the leachates obtained from each drum were of two types: an occasional residual leachate accumulated in the interim between water additions, and a drainage leachate obtained during the first 24 hr after liquid addition. These leachates were collected and their respective volumes were measured. After adding liquids, the leachates were also analyzed for biological oxygen demand (BOD_5), pH, conductivity, and turbidity. For each drum, a composite leachate sample was collected by accumulating some of the individual leachate samples. The composite samples were analyzed for pH, conductivity, nitrate, chloride, total phosphate, sulfate, fluoride, organic nitrogen (Kjeldahl), iron, copper, lead, mercury, chromium, and barium. With some exceptions (see Appendix A) all analytical procedures were in accordance with Standard Methods.[6] (See Photograph VI-2a for leachate collection method.)

b. Sludge Analysis. The sludge used in each application to a drum was a composite of several samples, collected over a period of up to a month. Each composite sludge was analyzed for BOD_5, pH, organic nitrogen, total volatile acids, total organic content, total phosphate, and conductivity. In addition to these composites of individual sludge types, a mixed composite sample was accumulated of digested sludge samples obtained every two weeks from the three treatment plants at Oceanside. This composite sample consisted of some samples taken in the proportion of 2:1:1 from biweekly collected digested sludge samples from La Salina, Buena Vista, and San Luis Rey treatment plants, respectively. The proportion was approximately the relative quantities of digested sludges generated by each plant. The mixed composite sample was analyzed for copper, lead, mercury, chromium, iron, barium, calcium, total hardness, and chloride.

a. DRUM LEACHATE MEASUREMENT AND SAMPLING.



b. METHANE/EXPLOSIVE GAS TEST EQUIPMENT.

c. HYPODERMIC GAS SAMPLER.

CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VI-2

TEST DRUM
MONITORING EQUIPMENT

c. Gas Sampling. At various intervals during the period of study, samples of gas were drawn from an intermediate point (see Figure VI-1) within the mass of solid waste in each drum and analyzed by gas chromatography (using a Varian Aerograph Model A90 P3) for carbon dioxide, methane, oxygen, and nitrogen. Both holes were kept plugged with corks except when gas or leachate samples were being drawn. All gas samples were taken at times just prior to removing the drum lids (for liquid addition) or drain hole corks (for leachate collection). The gas sampling technique involved the insertion of a 16-in.-long hypodermic needle into the refuse via the gas sample port with provision for an airtight seal. A polyethylene bag was placed inside the barrel over the solid waste in order to further minimize air movement. The gas samples may thus be presumed representative of the gases present in the interstitial cavities in the lower portion of each drum, plus any of the head space gases that may have been pulled down through open channels during the drawing of the sample, but relatively free of air that may have entered during placement of the sample hose. (See Photograph VI-2b and c for gas sampling methods.)

d. Vectors and Microorganisms. Qualitative visual observations were made of the presence of insects and breeding colonies in the various drums. In some, the major species of the insects present were also identified.

e. Temperature Measurements. Temperature was measured prior to water application/leachate sampling. Temperatures measured were those of ambient air, air inside a special empty drum, and the solid waste. Solid waste temperatures were obtained by implanting a Weston Model 2265 (0 to 120 F scale) bimetal element thermometer with an 8-in. stem into the top center of the waste mass.

f. Settlement Analysis. Settlement was determined by dropping a 200-lb weight twice from a height of 1 ft, then measuring the distance of the waste surface below a reference point at the top of the drum with a ruler.

g. Odor Tests. Each time the drums were opened, an observer noted the strength and type of odor detected.

h. Check on Moisture Content. Moisture content in the drums was checked once within the first 20 to 127 days, once within 79 to 155 days after filling with solid waste, and monthly after one year since filling. Three methods were used for the determination of moisture content. The first method consisted of weighing the drums before and after each liquid addition and dividing the difference by the weight of the solid waste initially placed in the drums. The second method was based on the difference in weight between the total amount of liquid added and the total amount of leachate obtained. The third method consisted of determining the dry and wet weights of the representative waste samples from each drum.

i. Sample Handling. Gas samples were analyzed immediately after they were obtained. Drum leachate samples were stored in a refrigerator immediately after they were obtained. Leachate composite samples were stored at ambient temperature (70°F).

C. Results and Discussion

1. Liquid Application and Leachate Flow. The characteristics of sewage sludge and septic tank pumpings applied to the pilot test drums are shown in Table VI-4. Table VI-5 presents the pounds of liquid applied per 100 lb of solid waste to reach saturation in each drum. Except for the high dry weight values of 213, 272, 201 and 204, the drum saturation values are in good agreement with the laboratory test results which predicted a range of 60 to 180 lb of liquid per 100 lb dry weight solid waste based on both April 1971 Oceanside solid waste composition and annual data given in Tables IV-5 and IV-6, respectively. The drum saturation levels were clustered in the high end of the predicted absorption range; this was attributed to entrainment of liquid in the drum solid waste void spaces.

The ratio of the lb of water per lb of dry weight of solid waste and sewage sludge solids added to each of the 16 wet drums is shown in Figure VI-2. The rapid initial rise represents the high rate of water application during the first six months (3-gal per day) after which applications of 3-gal per month were made.

Table VI-6 presents actual water contents of the drums as found by weighing on two different occasions. The data in this table indicate that with the exception of only a few drums, there was a reduction in the water content of the drums during the period between the two water determinations. Comparison of the data in Table VI-6 with the data in Table VI-5 indicates that, with the exception of Drum 16, the actual water content of the waste in each drum was considerably less than the saturation value. This may be attributed to the loss of water during leachate sampling and unmeasured drain leakage.

2. Leachate Characteristics.

a. BOD_5 Content. The data on changes in the BOD_5 content of the fresh leachate are presented in the Appendix for each individual drum. Unless otherwise stated, the leachates referred to in this section are the "fresh" leachates from the drums. Fresh leachate is the leachate obtained within the first hour after each addition of water. "Residual" leachate is the leachate removed prior to leach water addition that had accumulated between water additions.

Figure VI-3 is a composite plot containing the BOD_5 values for all the drums. The three curves in this figure represent the maximum, the minimum, and the arithmetic average (20-day increments) of all the data points. The data in Figure VI-3 indicate that the BOD_5 increased to a peak sometime within the first 100 days of sludge application, and gradually decreased to become asymptotic thereafter. The initial increase in BOD_5 may be attributed to the breakdown and solubilization of complex organics in the solid waste and sludge. The liquid applications to drums were started between April 16 and July 17, with the majority of them (Drums 6 through 15, and 17) started in mid-June. The hot summer temperature thus might have contributed to some extent to the observed high initial BOD_5 levels. The subsequent decrease in BOD_5 may represent a gradual depletion of the more readily soluble organics due to bacterial oxidation.

TABLE VI-4
CHARACTERISTICS OF SEWAGE SLUDGE AND SEPTIC TANK PUMPINGS APPLIED TO PILOT TEST DRUMS

Sample by source	Drum application		Conductivity (mhos)	BOD_5 (ppm)	Total solids (%)	Total organics (% dry wt)	Total nitrogen (%)	Total phosphate (ppm)	Total vol. acids (ppm)
	Primary	Secondary							
Mixed sludges	1 -*	2 5	3800	3050	-	-	-	110	-
La Salina:									
Digested activated sludge	6 7 8 9	6 7 8 -	3800	3200	1.4	60.7	1.68	370	216
	14 15	14 -	4200	-	4.5	53.2	1.77	80	46
San Luis Rey:									
Primary raw	10 11	10 -	4000	-	1.2	61.6	-	-	-
Digested primary	12 13	12 -	3190	-	3.4	45.3	-	-	-
Septic tank pumpings:									
Thick	3	-	1900	1630	2.0	40.5	-	-	-
Thin	16	16	1200	130	-	-	-	-	-

[*] Indicates not applicable or analyses not completed.

TABLE VI-5
MOISTURE ABSORPTION TO SATURATE SOLID WASTE SAMPLES

	Lb liquid/100 lb solid waste	
Drum no.	Dry wt	Wet wt
1	213	164
6	188	145
7	188	145
8	151	116
9	272	210
10	188	145
11	201	155
12	92	71
13	161	124
14	204	158
15	169	130
16	57	43
17	175	135
Avg	174 dry wt	134 wet wt

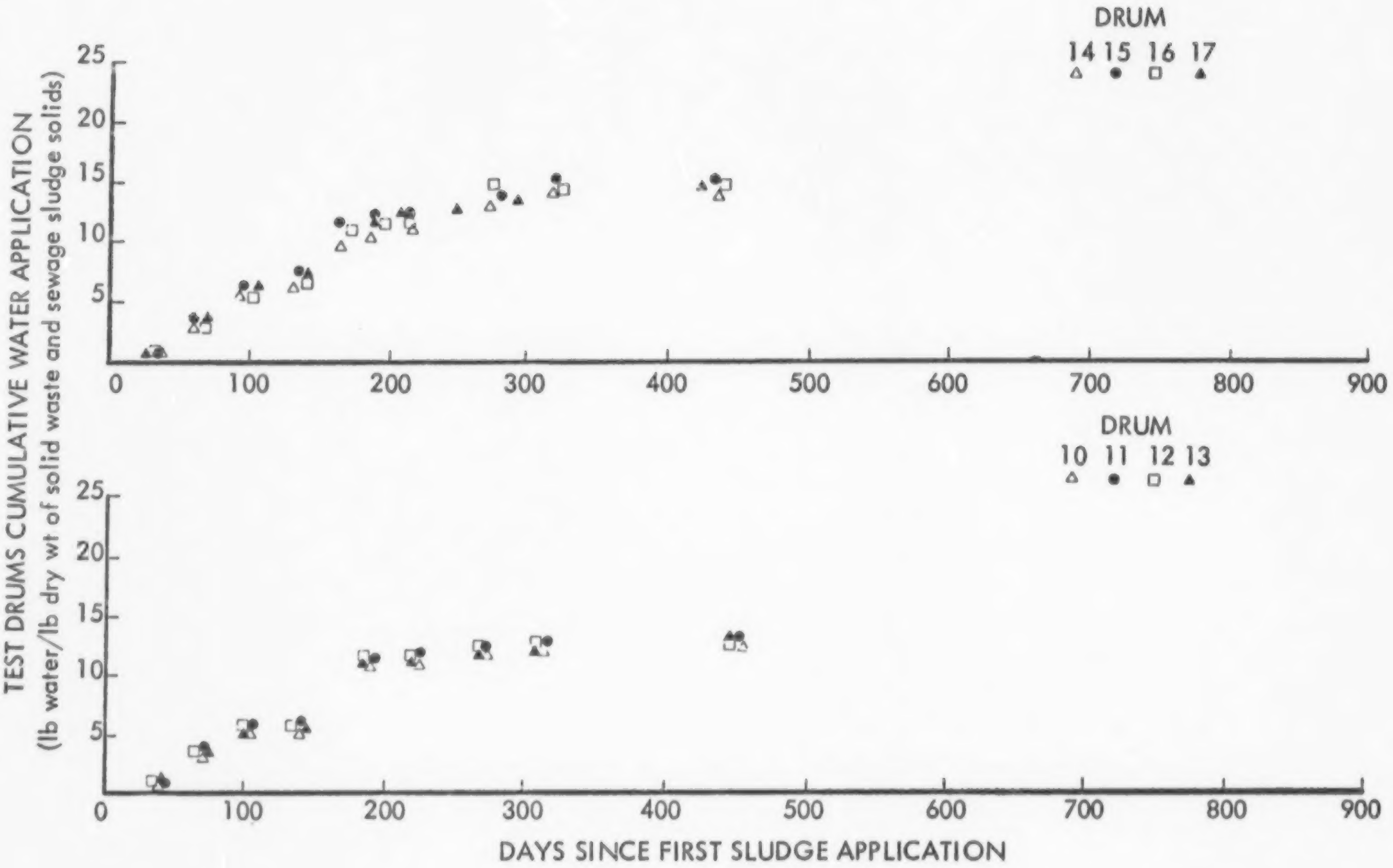


FIGURE VI-2A

TEST DRUM WEIGHT
RATIO OF WATER TO SOLIDS
ADDITIONS

CITY OF OCEANSIDE/E.P.A.

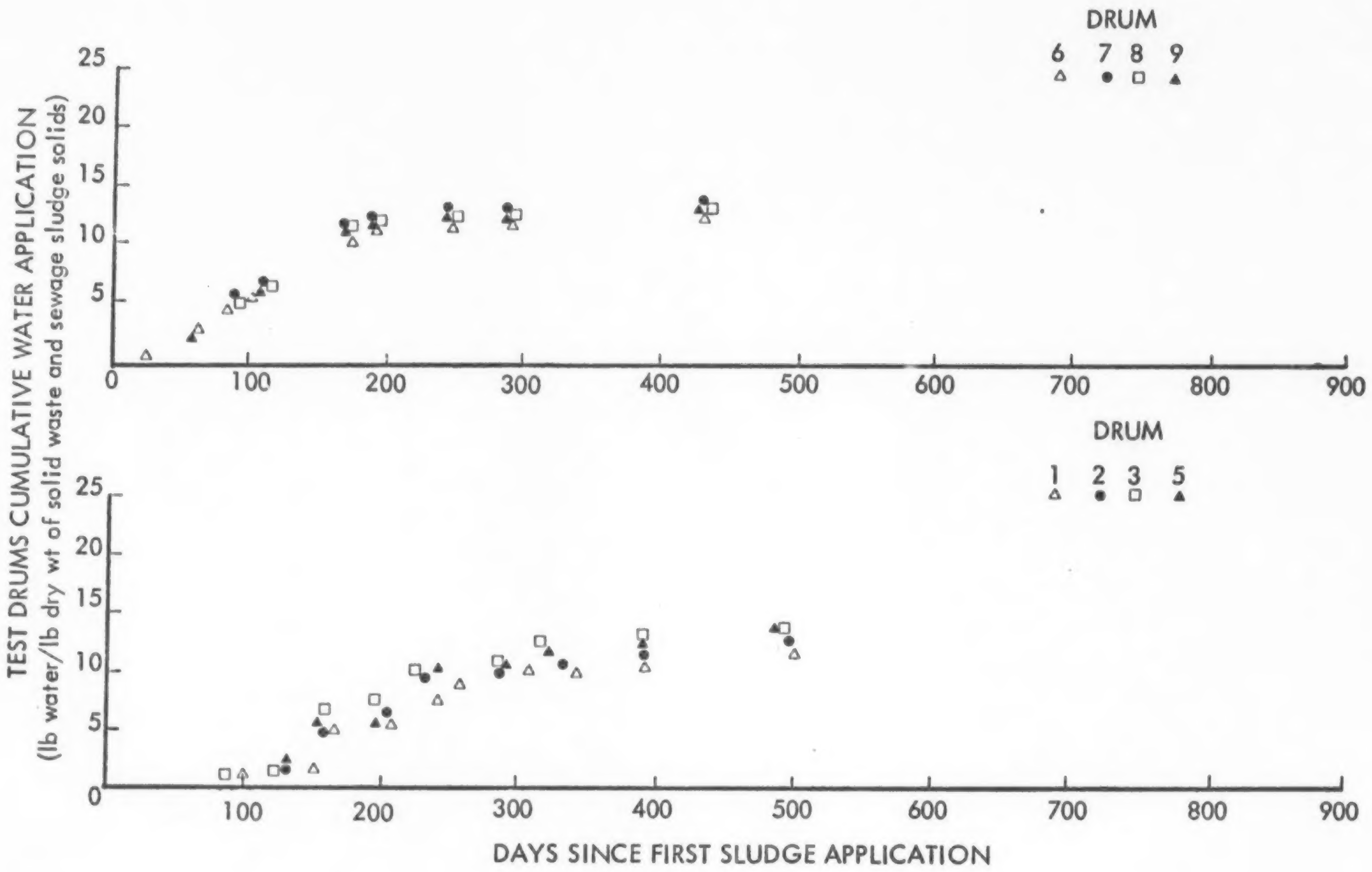


FIGURE VI-2B

TEST DRUM WEIGHT
RATIO OF WATER TO SOLIDS
ADDITIONS

TABLE VI-6
TEST DRUM WATER CONTENT DETERMINATIONS

Drum no.*	8/11/71		9/8/71	
	Wt (lb)	Percent wet wt	Wt (lb)	Percent wet wt
1	103	103	91	86
2	65	81	57	72
3	63	79	63	79
4	-+	-	23	29
5	102	128	94	117
6	60	76	54	67
7	20	29	36	45
8	33	42	25	33
9	62	77	45	56
10	47	59	50	62
11	-	-	41	51
12	30	38	24	30
13	20	26	18	23
14	46	58	23	29
15	-	-	20	25
16	33	41	34	42
17	32	40	30	37
18	-0.4	0	3	4

---

[*] Initial wet weight of solid waste placed in drums was: Drum 1 - 100 lb; Drums 2 through 18 - 80 lb.

[+] Not weighed.

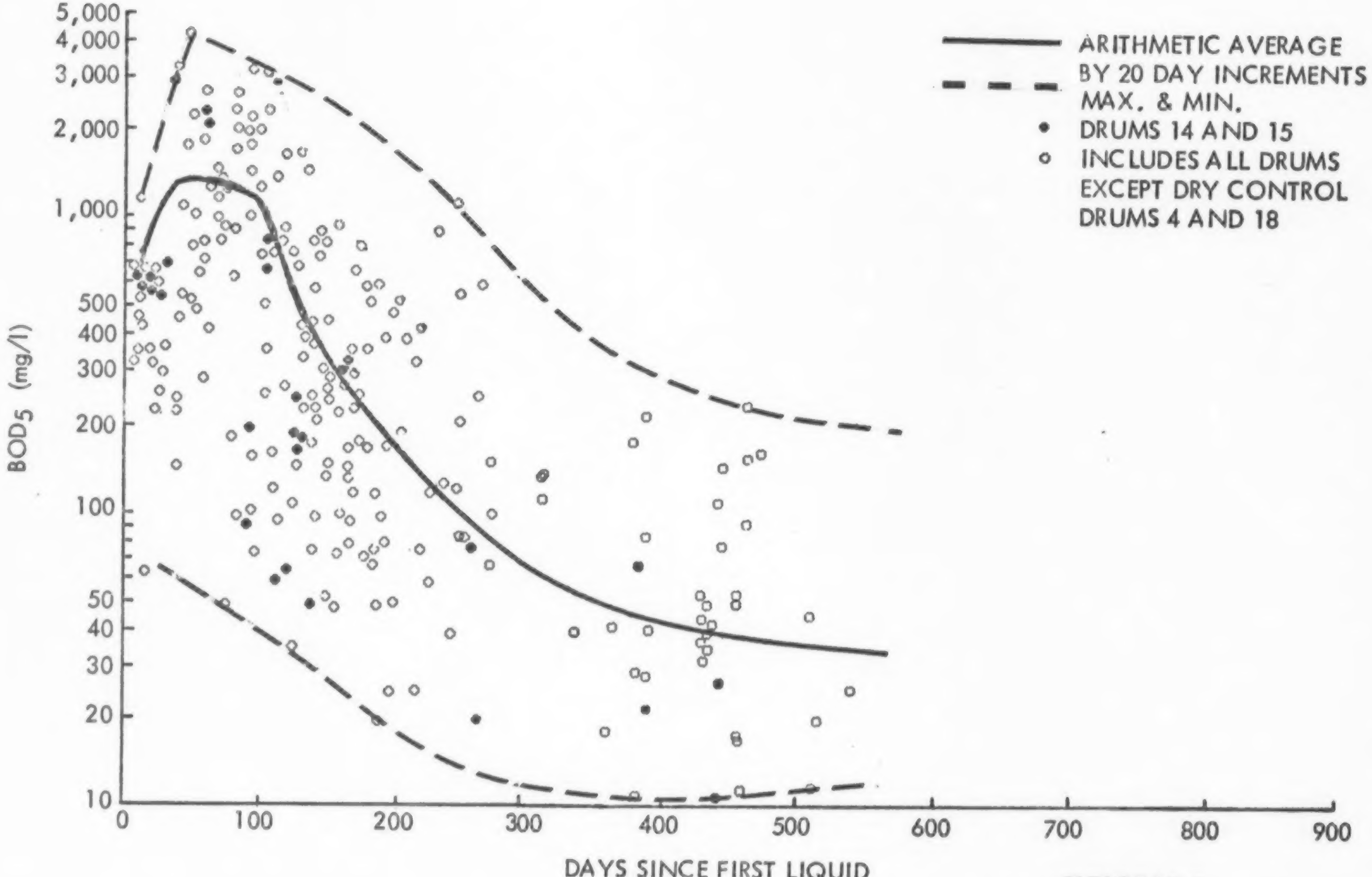


FIGURE VI-3
BOD5 LEVELS OF TEST DRUM
LEACHATES--DRUMS 14 AND 15
VS. COMPOSITE TRENDS

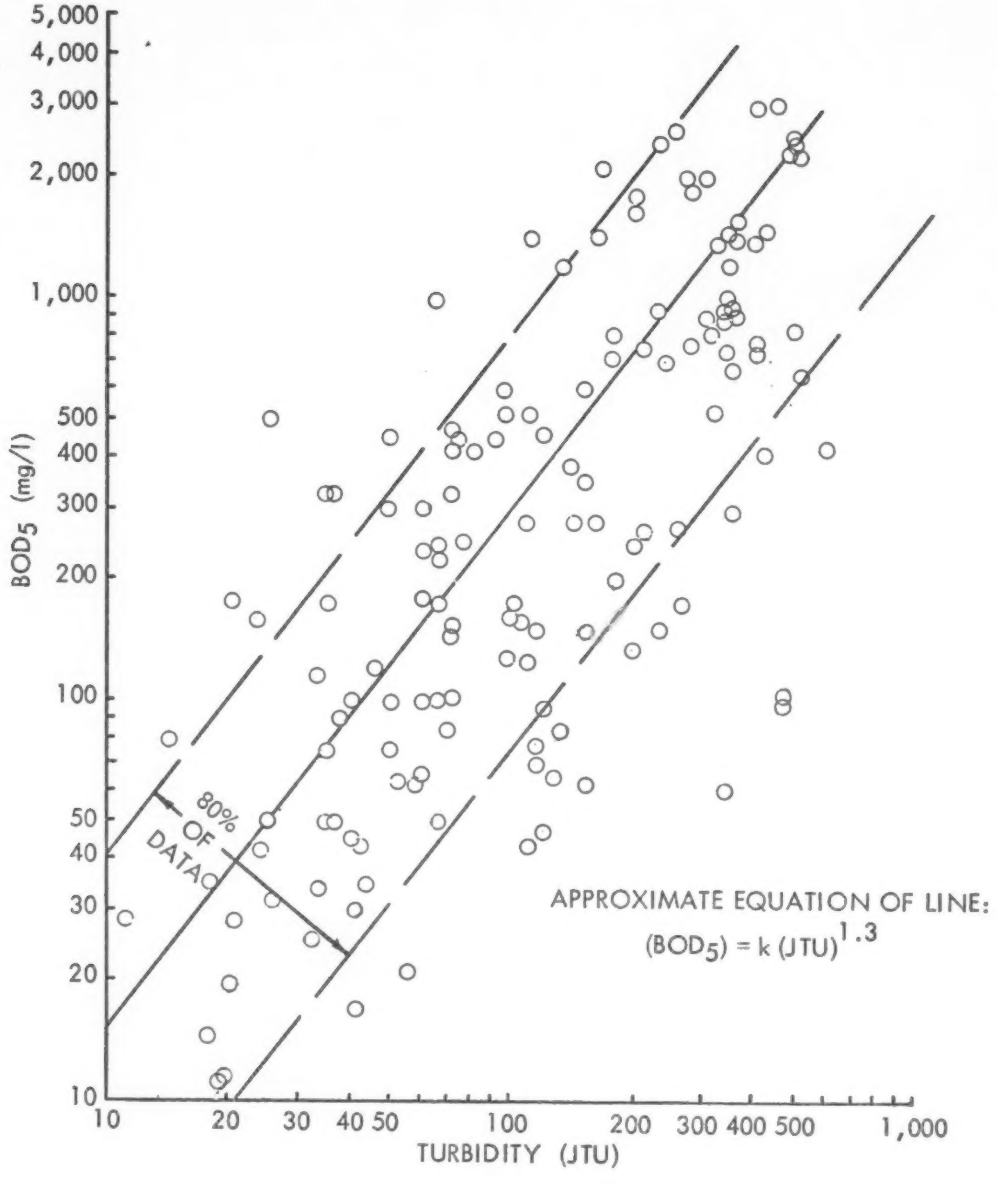
The data presented in Appendix D for individual drums indicate maximum BOD$_5$ values ranging from 350 mg/l for Drum 5 (charged with mixed digested sludge) to about 4,000 mg/l for Drum 13 (charged with digested primary sludge). Drum 12, which was a replicate of Drum 13, showed a maximum BOD$_5$ value of 2,500 mg/l. In general, with the exception of Drum 5, all drums (including those which had received water only) had maximum BOD$_5$ values of close to or in excess of 1,000 mg/l. This would indicate that, if BOD$_5$ can be considered a valid measure of the organic content of the liquid wastes, the quantity of organics discharged in the leachate would be primarily affected by the type and composition of the solid waste, and not so much by the kind of sludge applied during primary and secondary applications, or the weight ratio of sludge to solid waste used.

Figure VI-3 indicates the leachate BOD$_5$ trends of Drums 14 and 15 with the composite BOD$_5$ trend for all the drums. Drums 14 and 15 were the only two test drums which had been provided with forced aeration. Figure VI-3 indicates that, after reaching maximum values, the BOD$_5$ for Drums 14 and 15 dropped off initially at a faster rate than for most other drums,^{5} and then fell near the average for all drums. This would be expected since oxidation of organics generally proceeds at a faster rate under aerobic than anaerobic oxidation.

b. Color. The color observed in the leachates was initially black in seven drums, grey in five drums, and yellow or tea color in three drums. Most of the leachates were opaque in appearance. No relation was observed between the type of liquid applied and color; for example, leachates from drums which received water only were also black. The color changed with time to green, olive and yellow, to a straw color, and after 190 to 250 days, the colors were generally yellow or straw, clear or brownish.

In an actual landfill, the color of the leachate may be somewhat weaker than those observed in the test drums, since part of the color may be removed when the leachate percolates through the soil cover. (Two samples of leachate were obtained from the Oceanside landfill during May 1971; one sample was grey in color and the second was clear.)

c. Turbidity. The results of turbidity measurements on leachate samples are presented in Appendix D. In general, the changes in turbidity with time followed a pattern much similar to that of the BOD$_5$. To explore any correlation which may exist between the BOD$_5$ and turbidity of a leachate, the turbidity and BOD$_5$ values were plotted on a log-log paper. The results presented in Figure VI-4 indicate a lack of simple correlation between the two variables. This is not surprising since turbidity is a light-scattering phenomenon whose value is affected by the size, shape, and concentration of the particulate matter, whereas BOD$_5$$_5$ is only a measure of the biodegradable constituents (dissolved or particulate matter)^5 of the waste sample. Hence, inorganic particulate matter such as silt and iron oxide which contribute to turbidity do not exert BOD$_5$ demand. Similarly, soluble organic or reduced inorganic compounds which constitute BOD$_5$, do not register as turbidity.



CITY OF OCEANSIDE/E.P.A.

FIGURE VI-4
CORRELATION OF TEST DRUM
LEACHATE BOD_5 WITH TURBIDITY

d. Electrical Conductance (Conductivity). Electrical conductance is a measure of the capacity of a liquid to conduct electrical current. It is affected by the nature and concentration of charged species (mainly dissolved inorganic salts) in solution. A correlation exists between electrical conductivity and total dissolved solids of a liquid sample.

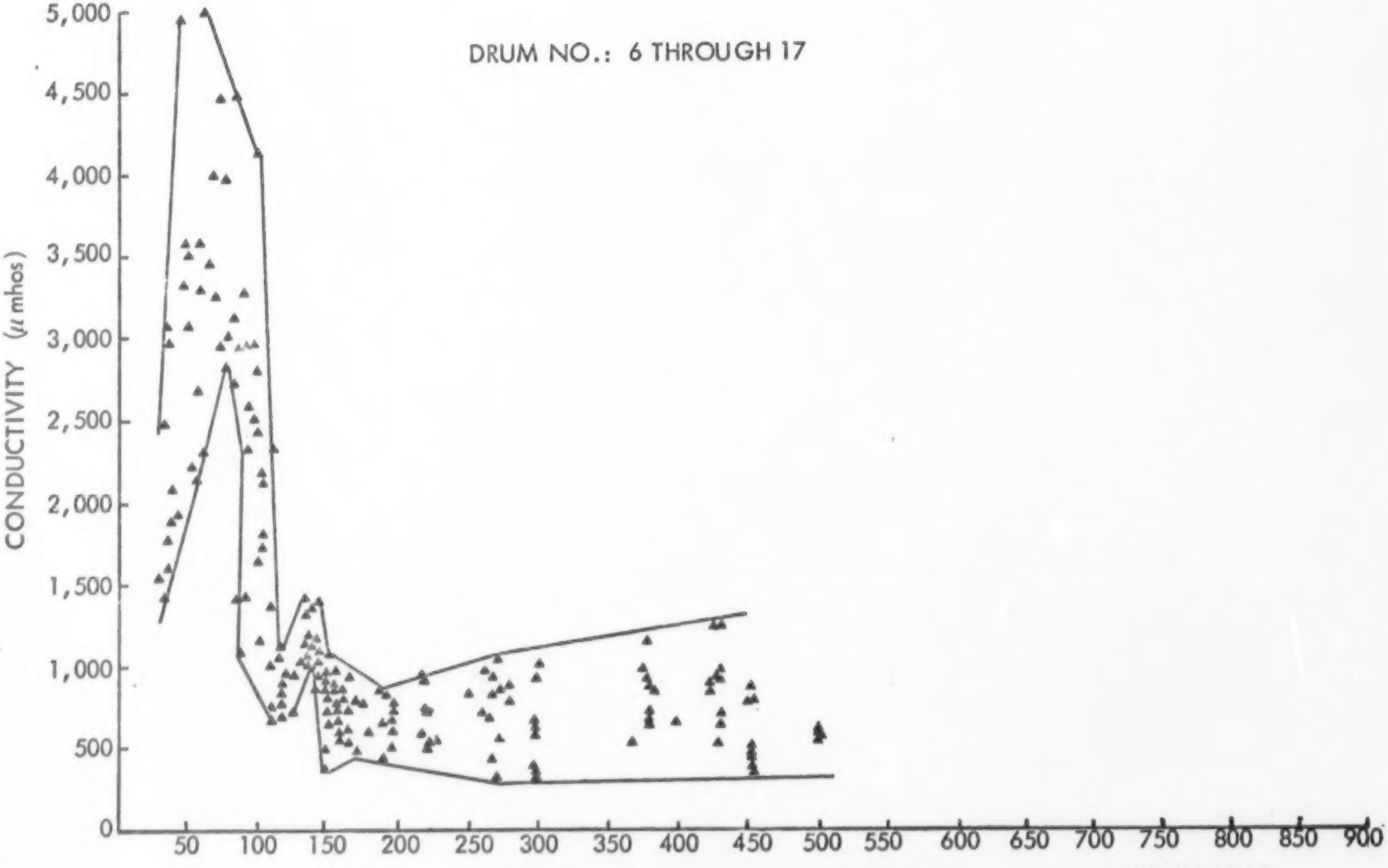
The dissolved inorganic content of solid waste leachates is important from the standpoint of its potential effect on groundwater quality. When leachates containing high salts content gain entrance to the groundwater, they may cause an appreciable increase in the salinity of the ground water and/or impart other undesirable properties to it.

The data on the conductivity of the leachate samples are presented in Appendix D. Figure VI-5 is a composite plot of conductivity values for Drums 6 through 17. A composite curve for Drums 2, 3 and 5 (see Appendix D) indicate similar peaks and asymptotically decreasing values for conductivity. They occur within roughly similar periods about 120 days after filling versus about 70 days as shown on Figure VI-5. Drums 2, 3 and 5 were filled about 50 days earlier than the other drums, which accounts for the different periods of sampling since filling to reach peak values. Drum 1 behaved differently in that its peak conductivity value occurred 30 days after filling which was 90 days prior to peaks on all other drums. The data in this figure and those presented in Appendix D indicate that the variation of conductivity with time is very similar to those of BOD_5 and turbidity, i.e., rising to a maximum within the first 100 days, decreasing and then becoming fairly constant. As with BOD_5 and turbidity, the pattern of change in conductivity may reflect variations in the rate of biodegradation and solubilization of the organic waste material. The conductivity data also indicate that, under the conditions of the experiments, the quality of the leachate was relatively insensitive to the kind and amount of liquid originally applied to the drums.

The second small peak occurring around 140 days on Figure VI-5 corresponded to a two-week period of increasing ambient air temperatures (see Figures VI-13 through VI-16). This indicates the temperature-dependence of the biological activity in the test drums.

In an exploratory effort to investigate any correlation which may exist between the conductivity and turbidity of a leachate sample, the conductivity values for the leachate samples were plotted against the corresponding turbidities on an arithmetic paper. The results presented in Figure VI-6 do not appear to indicate any simple direct correlation between the two variables. This is very understandable since turbidity is a measure of particulate matter in water whereas conductivity merely reflects the concentration of the charged species.

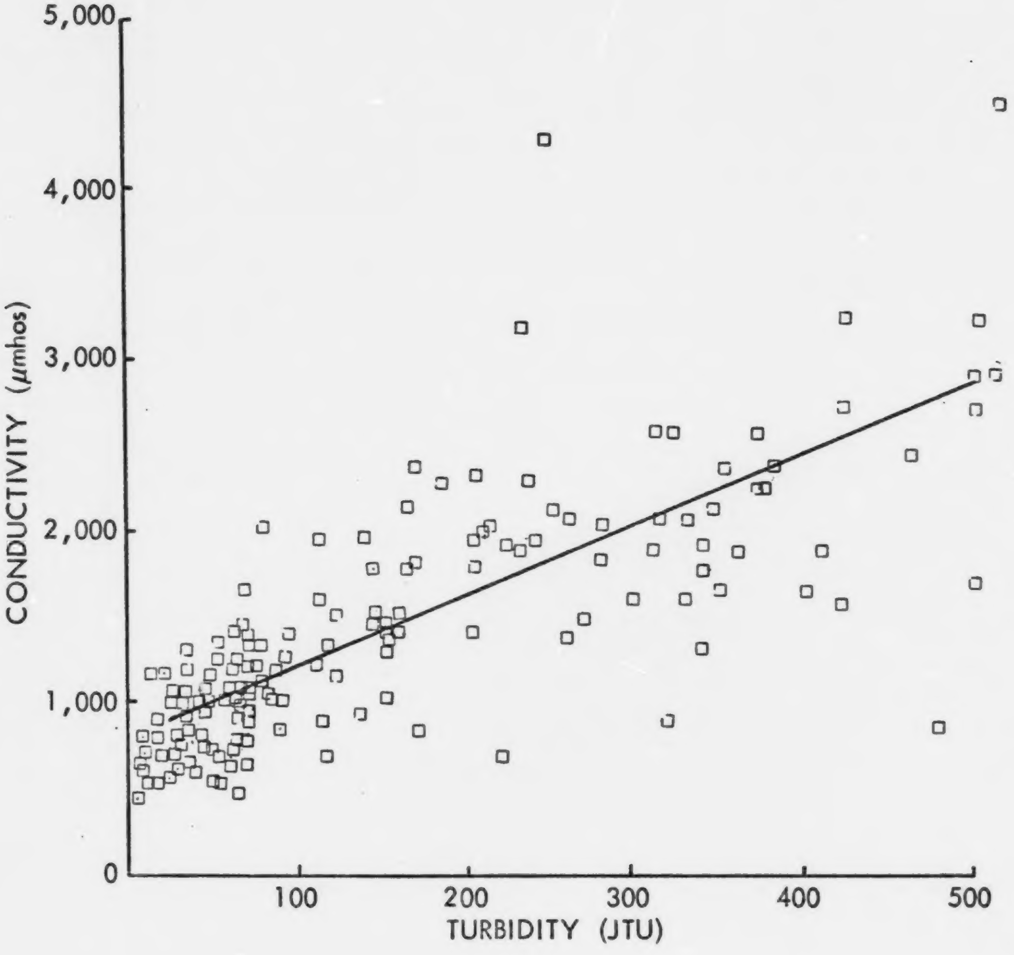
e. pH. The pH of the leachates are plotted individually for each drum in the Appendix D. In general, the changes in pH were fairly small and the pH values were all in the 5 to 8 range. In most cases, the pH dropped initially, reaching a minimum value within the first 100 days. The decrease in pH is probably due to the



CITY OF OCEANSIDE/E.P.A.

FIGURE VI-5

CONDUCTIVITY OF LEACHATES
COMPOSITE FOR
DRUMS 6 THROUGH 17



CITY OF OCEANSIDE/E.P.A.

FIGURE VI-6
CORRELATION OF CONDUCTIVITY
WITH TURBIDITY

formation of acidic end products resulting from the anaerobic biodegradation of organic wastes. Following the initial drop, the pH gradually increased, reaching values in the 6.2 to 7.2 range after 250 days. The increase in pH may reflect a slowdown in the rate of biodegradation of organics or reflect growth of methane producing bacteria which oxidize organic acids.

f. Comparison of Test Drum Leachate Characteristics With Landfill and Test Cell Leachates. Table VI-7 presents comparisons of test drum, test cell and landfill leachate characteristics for different ages of solid waste fill. Where ranges of values are given they represent maximum and minimum values for different samples (test cell and landfill) and different test drums. The data in Table VI-7 indicate that the test cell leachates were significantly stronger in BOD_5 than the test drum and landfill leachates. The high BOD_5, low pH, and foul odor of the test cell leachate are indications that extensive water to organic contact existed during or prior to the time of drainage and sampling. The data indicate that the leached soluble organics in Cell 1 were significantly greater than in the test drums during comparable time periods after filling. The low test drum BOD_5 range is attributed to the high rate of water application (12 to 15 lb water per lb dry wt solid waste) compared to Cell 1 which received 0.45 lb liquid per lb dry wt solid waste. The test drum water, having less contact time than liquid in Cell 1, apparently produced a diluted leachate and thus lower BOD_5.

g. Characteristics of "Fresh" and "Residual" Leachates. As it was described above in Section C.2., two types of leachates were obtained from each test drum: the "residual" (old) leachate collected at the bottom of drums due to the preceding liquid addition, and the "fresh" (new) leachate resulting immediately following each water addition. Table VI-8 presents typical data on quantity and quality of the residual and fresh leachates for the first sampling run. Additional residual leachate analyses are plotted in Appendix D with the fresh leachates. In the first sampling the old leachates appear to contain more turbidity and show higher conductivity and lower pH levels, but the BOD_5 data do not indicate any consistent pattern. In subsequent residual leachate analyses where there is complete data, BOD_5 and turbidities were greater for "residual" than for corresponding fresh leachates, but conductivity and pH were the same (see Appendix D). Based on BOD_5 and turbidity results, the residual leachate appears to have higher content of dissolved organic material than the fresh leachate. This may be due to the significantly longer solid-liquid contact time for the old leachate.

h. Specific Dissolved Salts. On several random occasions during the pilot drum tests, spot checks were made on free carbon dioxide, chloride, phosphate, calcium and nitrogen content of the leachates. The results are presented in Table VI-9. A running composite was kept of some portions of all leachate samples obtained from each drum. After the last sampling for 1971 in December, each composite sample was similarly analyzed. These results are given in Table VI-10.

The data in Tables VI-9 and VI-10 indicate no significant differences between the leachates from the various drums, thus confirming the general conclusion presented earlier that, in the drum tests, the leachate characteristics did not appear

TABLE VI-7

COMPARISON OF NATURAL AND SIMULATED LEACHATES

Measured variable	Field test cell 1, days since filling		Pilot test drums, days since filling		Old Oceanside landfill
	1st 57	211	1st 50	365 (1 yr)	Leachate age over 1 year*
BOD_5 (mg/l)	5,450 - 11,850	19,600	60 - 4,300	0 - 200	250 - 380
Turbidity (JTU)	53 - 210	74^+	40 - 510	0 - 100	#
Conductivity (μ mhos)	2,750 - 4,400	$4,000 - 6,500^+$	1,400 - 5,000	0 - 1,300	4,700 - 4,800
pH	4.6 - 5.5	5.9	5.0 - 8.6	5.0 - 7.8	5.1 - 5.2
Odor	Very sour	Very sour	Septic sulfide	Earthy	Sour

* Grab samples of leachate taken from small pools in cover soil on the side of the completed landfill about 20 feet below the top of the fill.

+ From samples taken 11/29/72 and 12/1/72, 294 and 296 days since filling, respectively. These are included for comparison.

# Not enough sample volume to complete analyses.

TABLE VI-8
COMPARISON OF FRESH AND RESIDUAL LEACHATES

	Residual leachate*					Fresh leachate[+]				
Drum no.	Qty (gal)	Turbidity (JTU)	Conductivity (μmhos)	pH	BOD$_5$ (mg/l)	Qty (gal)	Turbidity (JTU)	Conductivity (μmhos)	pH	BOD$_5$ (mg/l)
1	0	-	-	-	-	0.6[#]	65	2175	8.01	60
						Negl.	54	1170	7.28	
2	0.1	61	800	6.51	0	1.6	14	535	6.89	0
3	0.7	160	1550	7.01	6	1.7	17	595	6.75	16
5	0.3	155	1450	6.80	240	1.4	29	675	6.82	45
6	0	-	-	-	-	1.5[#]	6	610	7.36	0
7	Negl.**	35	1300	6.72	200	1.0	22	320	7.70	6
8	Negl.	48	1075	6.72	48	0.9	65	427	6.93	0
9	0	-	-	-	-	0.6[#]	70	1700	7.93	0
10	0.3	250	1600	6.56	0	2.0	52	505	6.63	285
11	0.8	230	2100	6.78	150	2.2	35	980	6.97	105
12	Negl.	125	1800	7.01	149	1.7	42	730	6.73	26
13	Negl.	170	2500	5.78	0	1.0	47	565	7.0	0
14	0	-	-	-	-	1.9	18	693	7.07	0
15	0	-	-	-	-	2.1	7.2	379	7.74	0
16	0.8	190	1600	6.79	150	1.6	33	725	7.00	45
17	1.4	180	2200	6.76	135	2.4	34	1030	7.01	150

* Samples of April 13, 1972 leachate remaining from last water application 40 days earlier.

[+] Leachate occurring within about 1/2 hour of water application.

[#] Leachate collected 3 days later from drums that did not drip measurable amounts within several hours of water application.

** Quantity of leachate enough for analyses, but insignificant in gallons.

TABLE VI-9
ANALYSES FOR SPECIFIC SOLUBLE COMPONENTS*

Drum no.	Dissolved CO_2+	All data in units of mg/l* Chloride+	Phosphate+	Calcium#	Total Nitrogen+	Nitrate#	Organic nitrogen¢
1	30	130	5	257	26.3	1.94	1.73
2	75	270	4	329	16.9	1.73	-
3	210	185	3	312	53.0	1.94	0.45
5	105	200	4	178	61.6	0.45	0.91
6	340	267	5	164	-	0.69	-
7	45	293	4	297	30.8	1.25	0.45
8	255	221	5	209	81.2	1.25	1.25
9	60	86	4	304	52.6	0.91	0.69
10	90	205	3	369	54.2	0.69	0.45
11	210	167	4	226	-	1.60	1.25
12	565	258	4	259	-	1.14	-
13	90	245	3	230	14.8	1.60	1.60
14	240	262	3	208	31.4	1.60	1.25
15	330	336	5	329	44.8	0.69	0.45
16	120	145	4	262	22.0	1.25	-
17	225	190	4	176	17.8	1.94	1.94

---

[*] Samples taken on dates as follows: + 9/10/71; # 9/14/71; and ¢ 9/24/71.

TABLE VI-10

CHEMICAL ANALYSES OF 1971 LEACHATE COMPOSITES *

Drum no.	F	Fe	SO_4	PO_4	Cl	Ca	NO_3	Conductivity	Total Organic Nitrogen	pH	Turbidity
1	0.10	0.12	100	1.0	225	74	0.30	1650	34	6.80	5
2	0.75	0.17	170	1.0	205	46	0.60	1150	45	7.35	14
3	0.50	0.21	42	0.80	200	81	0.90	1250	56	7.35	26
5	0.10	0.12	50	0.70	195	107	28.0	1300	62	7.00	18
6	0.35	0.10	96	0.45	140	116	0.70	1050	73	7.80	16
7	0.40	0.21	72	0.50	200	68	0.19	1400	72	7.90	24
8	0.50	0.21	86	0.45	190	78	0.83	1350	79	7.15	6
9	0.75	0.17	55	0.20	190	149	23.2	1350	17	7.15	13
10	0.67	0.21	56	1.00	220	129	2.00	1400	95	6.90	7
11	0.90	0.15	23	1.20	107	111	1.04	100	15	7.50	10
12	0.75	0.20	40	0.80	192	76	2.25	1500	60	7.85	45
13	1.00	0.12	34	0.80	182	111	1.37	1300	26	8.10	22
14	0.70	0.10	48	1.00	180	166	3.00	1150	31	7.40	8
15	0.65	0.23	78	1.00	110	57	1.16	875	46	7.80	9
16	0.50	0.25	72	0.50	190	73	20.0	1450	50	7.55	24
17	0.40	0.21	58	0.70	140	106	16.6	1250	41	7.05	25

* All values in mg/l; except pH, conductivity (μmhos/cm), and turbidity (JTU).

to be materially affected by the kind and amount of the liquid applied to the solid waste. Some differences which have been observed may in fact be related, at least partially, to differences which may have existed in the makeup of the solid waste placed in each drum. The fact that the nitrate(nitrogen oxide) values are significantly lower than the total organic nitrogen values suggests that oxidation of nitrogenous compounds which usually follows oxidation of carbonaceous material had not been advanced to any appreciable extent.

Analyses were also completed for heavy metals on the 1971 leachate composite, and a leachate composite accumulated in 1972. The results are given on Tables VI-11 and 12. Concentrations of lead, chromium, copper and manganese were all below 1 mg/l, or negligible. Concentrations of zinc and iron were generally slightly higher in the 1972 composite while magnesium was slightly lower. Apparently some zinc coatings on metals in the waste and perhaps some corrosion of the steel drums affected the results for zinc and iron.

3. Gas Generation. Table VI-13 presents the results of gas analysis for the 18 test drums. The analyses indicate extremely variable gas composition. Many of the drums indicated primarily air (Drums 2, 14 and 15). Drums 14 and 15 were aerated and, therefore, an air gas composition was expected. The remaining 15 drums showed varying amounts of carbon dioxide and several showed significant amounts of methane (Drums 1, 8, 9 and 13). The presence of CO_2 in all of the 15 drums is a good indication that aerobic decomposition occurred in the drums.

The variation in gas analyses resulted primarily from the existence of a comparatively large air space above the solid waste oxygenating each drum. The air space volume increased during each compaction/decomposition cycle, however, since the drums were opened at the top during water application, fresh air was introduced, and methane which is a lighter-than-air gas was easily lost. It was also suspected that taking gas samples from sidewall ports that did not extend into the waste mass allowed aeration via short-circuiting of the gas samples; the sample drew gases from along the sidewall gap and perhaps from the air mixture above.

Two methods were adopted in June 1972 in an attempt to better replicate landfill gas sampling conditions. Rubber septums were placed over the gas sample ports and samples were drawn using a 12-inch long hypodermic needle that was inserted into the middle of the solid waste mass. Also, polyethylene bag covers were loosely placed over the tops of the solid waste mass and sealed at the drum lid to minimize the drum air pocket. The gas analyses after June 1972 show increases in methane in Drums 8, 9, 10, 12, 13 and 17. Air contamination still remained a problem in the drums due to the need to remove the polyethylene bag seals to apply water. The drums other than the aforementioned drums had greater aeration occurring probably due to sealing failures; slight leaks can cause significant aeration in small test containers. Special high vacuum seals must be used to avoid air leaks.

TABLE VI - II

HEAVY METAL ANALYSIS OF 1971 LEACHATE COMPOSITES

	Concentration, mg /l					
Drum No.	Pb	Cr	Mg	Cu	Mn	Zn
1	< 0.07	< 0.03	15.0	0.05	< 0.02	0.60
2	< 0.07	< 0.03	11.7	< 0.015	< 0.02	0.53
3	< 0.07	< 0.03	12.2	< 0.015	< 0.02	0.20
5	< 0.07	< 0.03	14.6	< 0.015	< 0.02	0.30
6	< 0.07	< 0.03	11.9	< 0.015	< 0.02	0.55
7	< 0.07	< 0.03	14.2	< 0.015	< 0.02	0.20
8	< 0.07	< 0.03	14.2	< 0.015	< 0.02	0.20
9	< 0.07	< 0.03	15.0	< 0.015	< 0.02	0.25
10	0.4	< 0.03	14.2	< 0.015	< 0.02	0.40
11	< 0.07	< 0.03	15.4	< 0.015	< 0.02	0.25
12	< 0.07	< 0.03	6.0	< 0.015	< 0.02	0.45
13	< 0.07	< 0.03	13.6	< 0.015	< 0.02	0.20
14	< 0.07	< 0.03	12.2	< 0.015	< 0.02	0.20
15	< 0.07	< 0.03	6.2	< 0.015	< 0.02	0.25
16	0.4	< 0.03	12.1	0.1	< 0.02	0.50
17	< 0.07	< 0.03	11.5	< 0.015	< 0.02	0.30

TABLE VI - 12

HEAVY METAL ANALYSIS OF 1972 LEACHATE COMPOSITES

	Concentration, mg /l						
Drum No.	Fe	Pb	Cr	Mg	Cu	Mn	Zn
1	2.2	0.6	< 0.03	12.00	0.10	< 0.02	0.80
2	25.0	< 0.07	< 0.03	5.00	0.05	0.10	0.85
3	2.2	< 0.07	< 0.03	6.00	< 0.015	< 0.02	0.25
5	2.2	0.4	< 0.03	8.50	< 0.015	< 0.02	0.80
6	1.8	0.2	< 0.03	13.40	< 0.015	< 0.02	0.30
7	2.4	0.4	< 0.03	6.80	< 0.015	< 0.02	0.20
8	2.0	0.4	< 0.03	6.20	< 0.015	< 0.02	0.30
9	3.0	< 0.07	< 0.03	14.10	< 0.015	0.10	0.45
10	1.8	< 0.07	< 0.03	3.80	0.05	< 0.02	0.20
11	8.2	< 0.07	< 0.03	15.00	0.05	< 0.02	0.25
12	2.2	< 0.07	< 0.03	12.80	< 0.015	0.20	1.75
13	2.0	0.2	< 0.03	6.80	< 0.015	< 0.02	0.30
14	2.2	< 0.07	< 0.03	9.00	< 0.015	0.20	1.75
15	2.2	< 0.07	< 0.03	1.10	< 0.015	< 0.02	0.30
16	4.4	0.6	< 0.03	10.00	< 0.015	< 0.02	1.55
17	2.2	0.4	< 0.03	11.70	< 0.015	< 0.02	0.53

TABLE VI-13
COMPOSITION OF GAS SAMPLES FROM TEST DRUMS @

Drum no.	Date	Day *	Gas composition (percent by volume)				Drum no.	Date	Day *	Gas composition (percent by volume)			
			CO_2	O_2	N_2	CH_4				CO_2	O_2	N_2	CH_4
	1971							1971					
$1^{+,\#}$	8/6	122	0	18.1	82.1	0	$2^{\#}$	8/6	98	0	21.0	79.0	0
	8/11	127	42.5	3.8	25.9	27.8		8/11	103	0.4	20.6	79.0	0
	8/26	142	32.2	4.6	44.6	18.6		8/26	118	0.1	20.9	79.0	0
	9/14	161	7.9	0.5	59.2	32.4		9/14	137	0	19.9	80.1	0
	11/17	224	2.3	20.0	77.7	0		11/17	200	1.8	20.1	78.1	0
	12/29	265	9.0	14.1	60.9	16.0		12/29	224	0	18.1	81.9	0
	1972												
	1/19	286	12.1	14.5	62.7	10.7		1972					
	6/28	447	12.0	0.3	87.7	0		6/28	Inaccurate - Air leak into drum.				
	8/14	513	8.8	6.0	85.2	0							
	9/18	548	12.0	6.5	81.3	0.2		9/18	488	30	14.4	82.6	0

@ For key to footnotes see page 110

TABLE VI-13

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS @

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4	Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971							1971					
3	8/6	98	0	21.0	79.0	0	4 **	8/6	95	0	20.0	80.0	0
	8/11	103	0	21.0	79.0	0		8/11	100	0	21.4	78.6	0
	8/26	118	19.0	4.2	76.8	0		8/26	115	8.2	16.2	76.6	0
	9/14	137	25.5	3.3	71.2	0		9/14	137	21.5	10.5	60.2	7.8
	11/17	200	5.6	17.0	77.4	0		11/17	200	5.9	16.5	77.6	0
	12/29	239	2.8	17.6	79.6	0		12/29	241	5.2	18.0	76.8	0
	1972							1972					
	1/19	260	4.6	16.8	78.6	0		1/19	262	5.2	16.3	78.1	0.4
	6/28	421	9.5	7.6	82.9	0		6/28	423	2.2	13.1	84.7	0
	8/14	468	17.3	0.3	82.4	0		8/14	470	2.9	17.1	80.0	0
	9/18	499	14.6	4.2	81.2	0		9/18	501	6.5	12.4	81.1	0

@ For key to footnotes see page 110

TABLE VI-13

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS [@]

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4	Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971							1971					
5#	8/11	103	6.8	15.7	77.5	0	6#	8/6	52	31.2	2.6	59.5	6.7
	8/26	118	7.4	17.6	75.0	0		8/11	57	12.0	12.0	76.0	0
	9/14	137	9.8	8.0	82.2	0		8/26	73	10.2	11.5	78.3	0
	11/17	200	6.9	14.9	78.2	0		9/14	92	9.3	14.7	76.0	0
	12/29	239	7.7	17.0	74.9	0.4		11/17	155	12.2	10.3	77.5	0
	1972							12/29	196	3.0	18.0	79.0	0
	1/19	260	7.6	14.0	78.4	0		1972					
								1/19	217	12.6	9.2	78.2	0
	6/28	421	4.5	9.2	86.3	0		6/28	378	Inaccurate - Air leak into drum.			
	8/14	468	11.2	7.3	81.5	0		8/14	425	11.2	7.3	81.5	0
	9/18	499	9.5	9.1	81.4	0		9/18	456	8.5	11.3	80.2	0

[@] For key to footnotes see page 110

TABLE VI-13
COMPOSITION OF TEST SAMPLES FROM TEST DRUMS @

			Gas composition (percent by volume)							Gas composition (percent by volume)			
Drum no.	Date	Day *	CO_2	O_2	N_2	CH_4	Drum no.	Date	Day *	CO_2	O_2	N_2	CH_4
	1971							1971					
7	8/6	51	3.5	17.8	78.7	0	8	8/11	51	0	21.0	79.0	0
	8/11	56	0	20.7	79.3	0		8/26	66	3.4	19.4	77.2	0
	8/26	72	2.7	20.3	77.0	0		9/14	85	0	21.1	78.9	0
	9/14	93	11.5	11.5	77.0	0		11/17	148	13.0	10.2	74.8	2.0
	11/17	155	4.7	17.2	78.1	0							
	12/29	195	5.8	14.5	79.7	0.3							
	1972							1972					
	1/19	216	6.8	14.6	78.6	0		1/19	211	12.3	9.4	77.1	1.2
	6/28	377	Inaccurate - Air leak into drum.					6/28	372	19.3	0.1	66.2	14.4
	8/18	428	5.2	12.2	82.6	0		8/18	423	24.5	0.1	55.4	20.0
	9/18	459	2.8	15.7	81.6	0		9/18	454	22.7	1.9	60.6	14.8

@ For key to footnotes see page 110

TABLE VI-13

COMPOSITION OF TEST SAMPLES FROM TEST DRUMS @

Drum no.	Date	Day *	Gas composition (percent by volume)				Drum no.	Date	Day *	Gas composition (percent by volume)			
			CO_2	O_2	N_2	CH_4				CO_2	O_2	N_2	CH_4
	1971							1971					
9	8/11	51	7.2	17.0	75.8	0	10	8/6	56	29.6	3.4	65.8	1.2
	8/26	66	31.2	4.7	54.0	10.1		8/11	61	12.8	12.4	74.8	0
	9/14	85	7.5	17.2	75.3	0		8/26	76	25.1	2.4	72.5	0
	11/17	148	3.5	19.3	75.8	1.3		9/14	95	25.9	2.1	72.0	0
	12/29	178	4.1	17.8	77.4	0.7		11/17	158	13.3	10.4	76.3	0
	1972							1972					
	1/19	199	3.6	17.9	76.5	2.0		1/19	221	9.8	12.7	77.5	0
	6/28	360	27.2	1.0	24.5	47.4		6/28	382	12.4	1.1	85.9	0.6
	8/18	411	48.8	0.3	41.5	9.4		8/18	433	20.3	1.0	76.2	2.5
	9/18	442	33.4	0	26.4	40.2		9/18	464	23.1	0.4	74.8	1.7

@ For key to footnotes see page 110

TABLE VI-13

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS @

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
11	8/6	56	0	20.8	79.2	0
	8/11	61	1.7	22.6	75.7	0
	8/26	76	19.0	9.0	72.0	0
	9/14	95	3.9	18.9	77.2	0
	11/17	158	5.4	16.6	78.0	0
	12/29	200	5.6	18.9	75.5	0
	1972					
	1/19	221	8.2	14.1	77.7	0
	6/29	383	4.3	12.0	83.7	0
	8/18	433	20.0	0.4	79.0	0.6
	9/18	464	18.5	0.9	80.6	0

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
12	8/11	61	0	21.8	78.2	0
	8/26	76	20.0	6.0	74.0	0
	9/14	95	13.5	9.5	77.0	0
	11/17	158	5.5	16.1	78.4	0
	1972					
	1/19	179	3.5	18.1	78.4	0
	6/29	341	20.2	1.8	41.6	36.4
	8/18	391	15.8	0.5	83.7	0
	9/18	421	40.0	2.7	17.0	40.3

@ For key to footnotes see page 110

TABLE VI-13
COMPOSITION OF GAS SAMPLES FROM TEST DRUMS [@]

Drum no.	Date	Day *	Gas composition (percent by volume) CO$_2$	O$_2$	N$_2$	CH$_4$	Drum no.	Date	Day *	Gas composition (percent by volume) CO$_2$	O$_2$	N$_2$	CH$_4$
	1971							1971					
13	8/6	56	4.0	19.2	76.8	0	14[++]	8/6	46	27.2	12.0	48.4	12.4[##]
	8/11	61	3.7	19.4	76.9	0		8/11	51	5.0	17.2	77.8	0
	8/26	76	8.2	16.2	76.6	0		8/26	66	8.0	18.8	67.7	5.3[##]
	9/14	95	26.5	3.0	70.5	0		9/14	75	0	20.9	79.1	0
	11/17	158	5.2	16.0	77.9	0.9		11/17	148	0	19.0	81.0	0
	12/29	200	5.2	15.2	79.0	0.6							
	1972												
	1/19	221	3.8	17.6	76.4	2.2		1972					
	6/29	383	26.3	0.3	47.8	25.6		6/29	310	0	21.1	78.9	0
	8/18	433	25.8	0.1	36.1	38.0		8/18	423	2.4	16.7	80.9	0
	9/18	464	39.1	0.1	10.0	50.8		9/18	454	0	20.3	79.7	0

[@] For key to footnotes see page 110

TABLE VI-13
COMPOSITION OF GAS SAMPLES FROM TEST DRUMS @

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4	Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971							1971					
15++	8/11	51	0	20.0	80.0	0	16	8/11	28	8.2	10.6	76.8	4.4
	8/26	66	18.0	11.0	66.0	5.0##		8/26	43	0	20.8	79.2	0
	9/14	75	0	18.5	81.5	0		9/14	62	3.5	17.3	79.2	0
	11/17	148	0	18.9	81.1	0		11/17	125	6.2	15.9	77.9	0
	12/29	180	0	20.0	80.0	0		12/29	165	4.5	17.2	78.3	0
	1972							1972					
	6/29	342	0	20.8	79.2	0		1/19	186	10.4	12.1	77.5	0
	8/14	409	3.2	16.1	80.7	0		6/29	348	4.8	10.0	85.2	0
	9/18	434	0	20.4	79.6	0		8/18	398	12.4	1.5	86.1	0
								9/18	429	10.3	8.2	81.5	0

@ For key to footnotes see page 110

TABLE VI-13

COMPOSITION OF GAS SAMPLES FROM TEST DRUMS @

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
17	8/6	50	0	19.2	80.8	0
	8/11	55	0	20.7	79.3	0
	8/26	70	0.5	15.1	84.4	0
	9/14	89	0	20.0	80.0	0
	11/17	152	2.1	19.6	78.3	0
	12/29	194	1.7	19.7	78.6	0
	1972					
	6/29	354	6.7	10.1	83.2	0
	8/14	423	40.7	0.2	30.8	28.3
	9/18	458	30.0	3.3	47.5	19.2

Drum no.	Date	Day *	Gas composition (percent by volume) CO_2	O_2	N_2	CH_4
	1971					
18**	8/11	63	12.0	12.0	76.0	0
	8/26	78	25.5	1.5	73.0	0
	9/14	97	27.7	1.8	70.5	0
	11/17	160	8.5	14.1	77.4	0
	12/29	202	5.4	15.2	79.4	0
	1972					
	1/19	223	8.8	14.0	77.2	0
	6/29	385	11.2	6.4	82.4	0
	8/14	431	15.8	0.5	83.7	0
	9/18	466	19.7	0.4	79.9	0

@ For key to footnotes see page 110

TABLE VI -13
KEY TO FOOTNOTES

[*] Days since initial sludge, septic tank pumpings or water application.

[+] Solid waste and sludge mixture; older, denser, and more compact than other drums.

[#] These drums suspected of air leakage.

[**] Dry control drum. No liquids applied.

[++] Forced aeration, through drum from top to bottom. Blower operating cycle five minutes every two hours.

[##] Aeration blower temporarily out of operation at this time.

4. Compaction. The material in the drums was compacted prior to each water application to simulate the preload found at landfills from cover soil and vehicular travel. The degree of settlement after compaction, expressed as percent reduction in the depth of solid waste, is plotted against days since filling in Figures VI-7 through VI-11. The curves included in Figure VI-8 were generally somewhat steeper and show greater settlement than those included on Figures VI-7, VI-9, VI-10 and VI-11.

Figure VI-9 contains settlement curves which, because of the special conditions in the drums, exhibited characteristics somewhat different from those included in Figures VI-7, VI-8, VI-10 and VI-11. Drum 1, for example, was compacted to a greater initial density, contained 32.5 percent more solid waste, and was more thoroughly saturated with sludge than all other drums. The upper layers in the drum were also arranged in such a way as to prevent run-through. These initial conditions resulted in a relatively dense mass and hence a smaller degree of settlement. As indicated in Figure VI-9, Drums 14 and 15, with forced aeration, showed slower settling rates than the dry control Drums 4 and 18. Comparison of Drums 14 and 15 with the others, as grouped in Figures VI-7 through VI-11, indicates no significant correlation between settlement rates with forced aeration and without. Also, the rates of settlement in the dry control Drums 4 and 18 were actually faster than several of those receiving liquid applications.

It may, therefore, be concluded that any variation in settlement rate resulting from the kind or quantity of liquid application was relatively insignificant and was masked by random factors affecting the rate of settlement. The random factors are presumably related to the size, shape, and arrangement of the relatively larger objects used in the solid waste composition. For example, a thick magazine, a folded newspaper, or a piece of corrugated cardboard standing vertically will resist compression far differently than if it were lying flat or torn apart and crumbled. A heavy can, bottle, or piece of wood remains relatively incompressible when cushioned by paper and food waste, while a handful of lettuce leaves essentially turns to liquid after a few days of decomposition, leaving a void. In an actual landfill, the effects of the above differences in material properties may be averaged out because of the better breakage and compaction; also, the maximum dimensions of the various objects are negligible in comparison with the minimum horizontal or vertical dimensions of the landfill. Thus solid waste in a landfill may tend to behave as a more uniform substance, and result in uniform settlement curves. The solid waste used in these pilot drum tests, on the other hand, although carefully selected with regard to composition and representative kinds of objects, because of the limiting boundary conditions due to the small ratio of drum dimensions to the size of the solid waste objects, lacked the effective structural homogeneity of the same blend of compacted materials on a large scale in a landfill. Nevertheless, in spite of these physical factors, the pilot plant settlement curves still exhibit the same general form as those of actual landfills (see Test Cell settlement, Section VII).

Somewhat related to the compaction experiments were some permeability tests conducted on December 15, 1971, in which the rate of leachate flow was

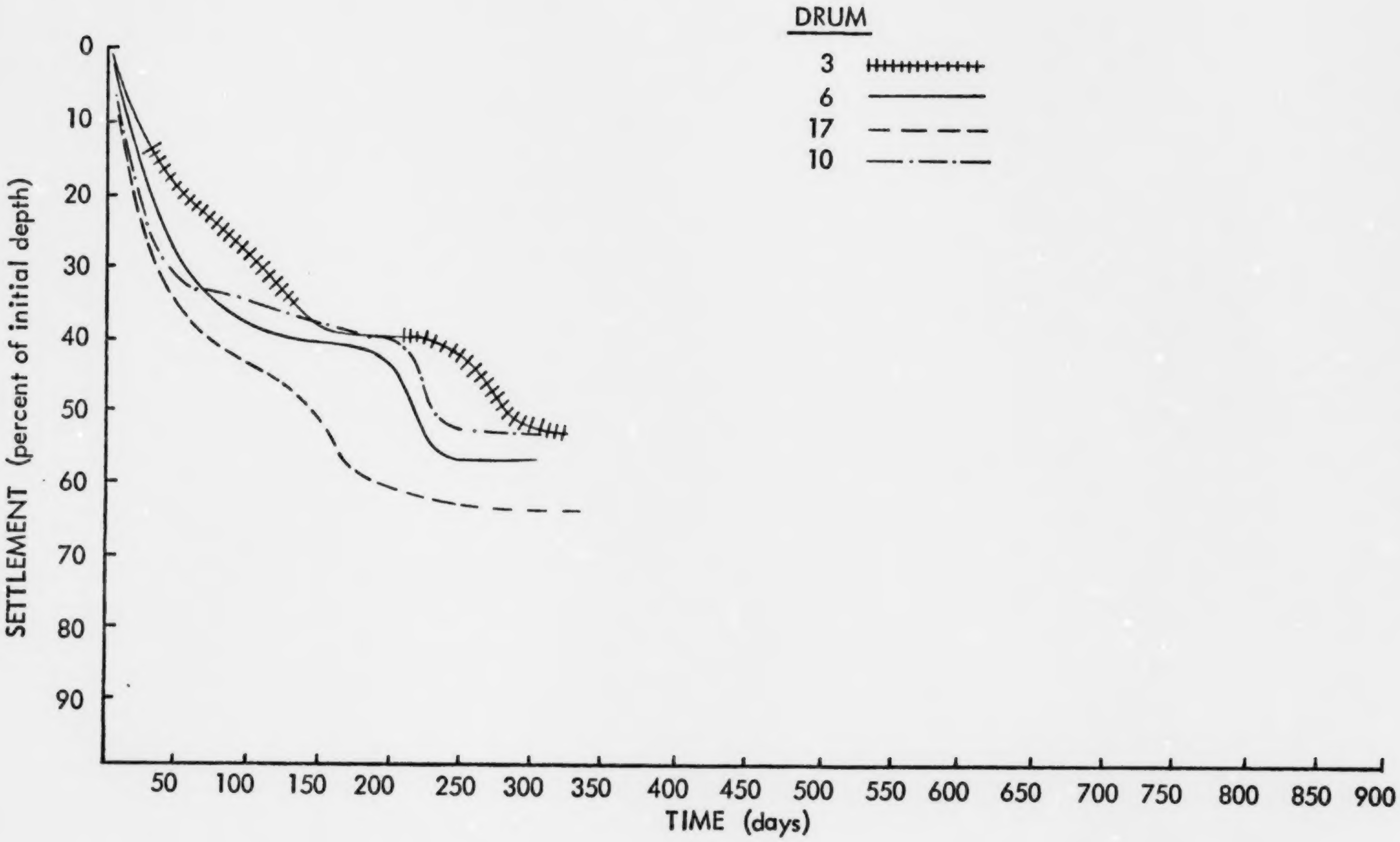


FIGURE VI-7

PILOT TEST DRUM
COMPACTION/SETTLEMENT
LOW RATE

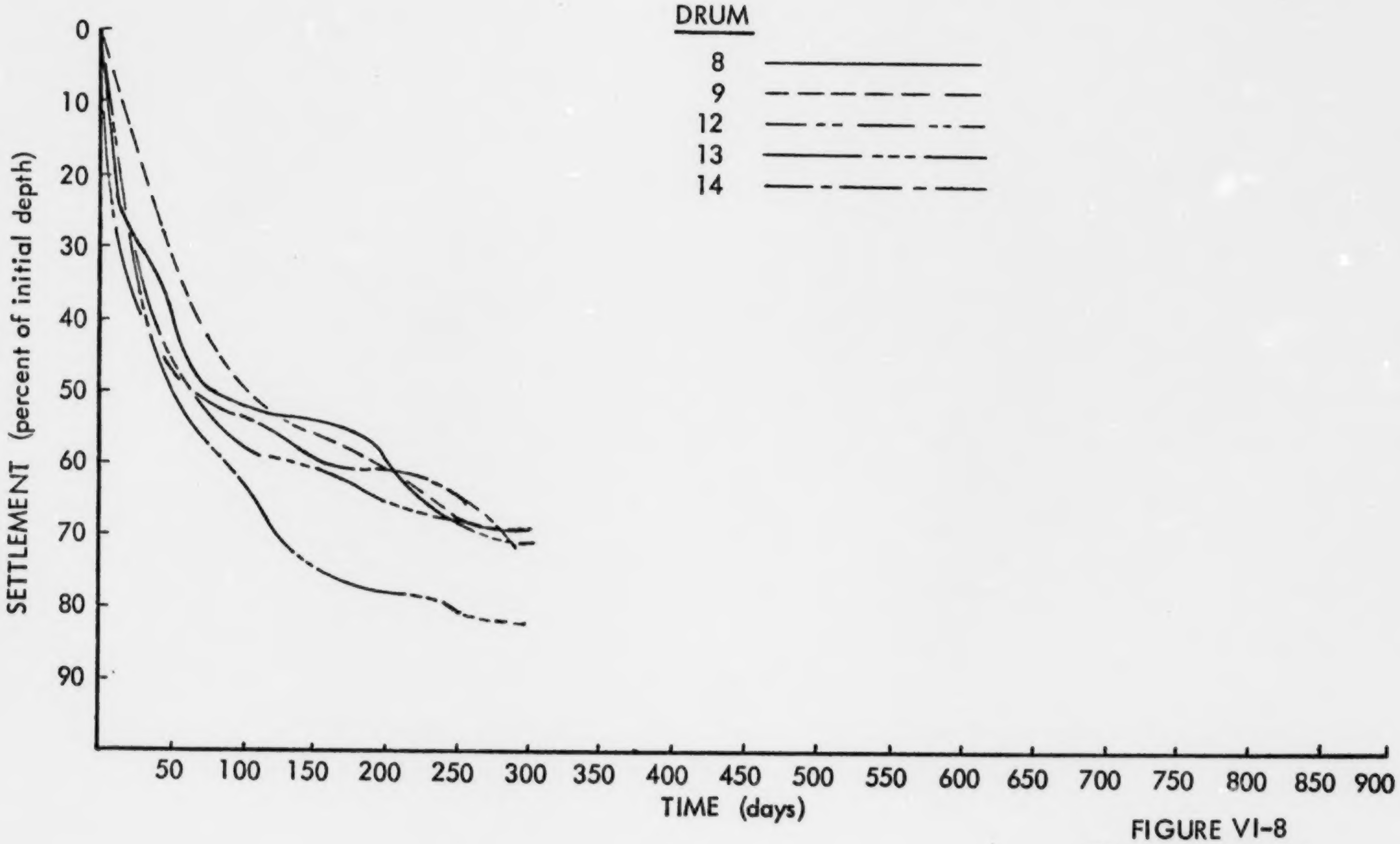


FIGURE VI-8
PILOT TEST DRUM
COMPACTION/SETTLEMENT
HIGH RATE

CITY OF OCEANSIDE/E.P.A.

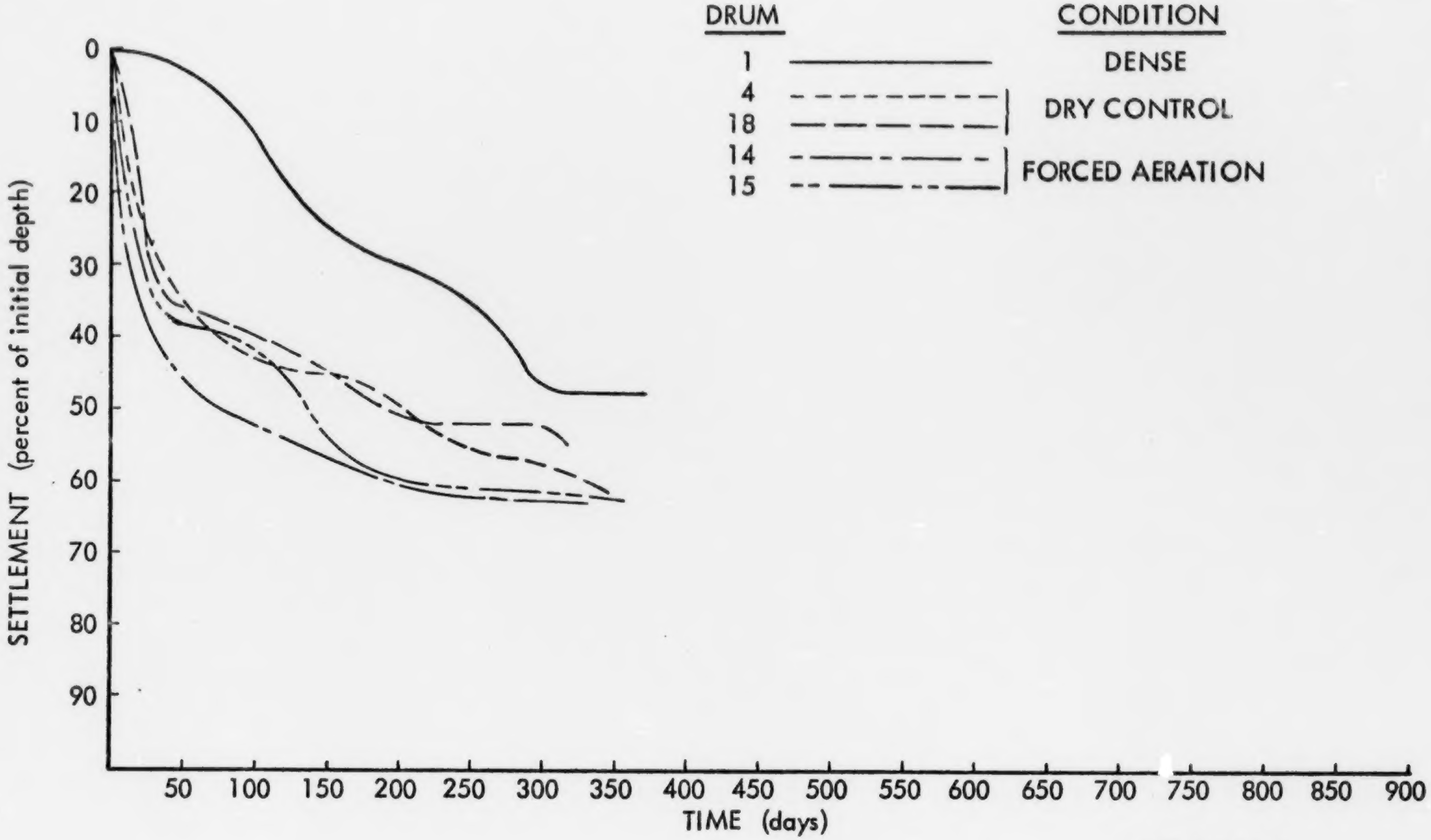


FIGURE VI-9
PILOT TEST DRUM
COMPACTION/SETTLEMENT
SPECIAL CONDITIONS

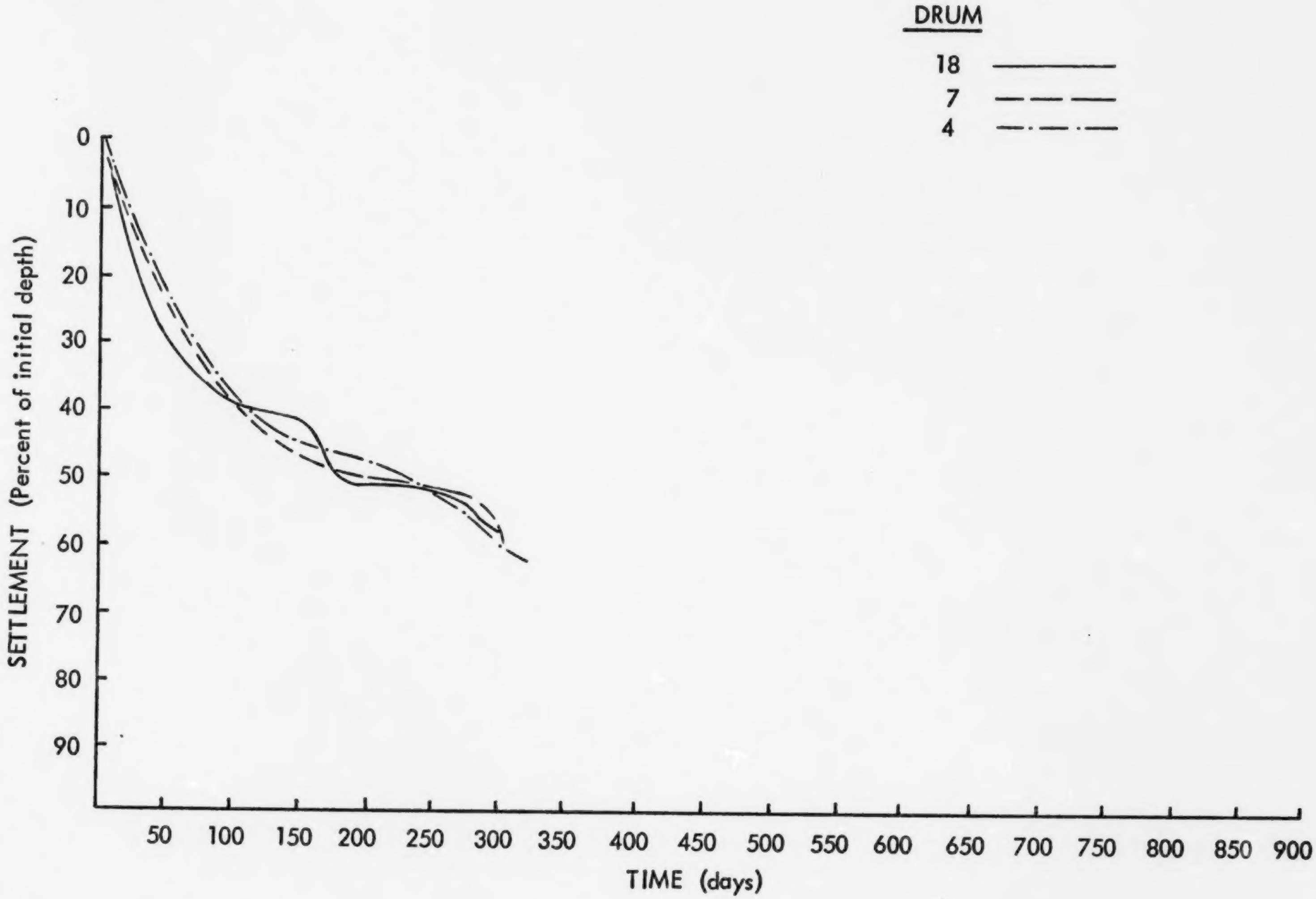


FIGURE VI-10

PILOT TEST DRUM
COMPACTION/SETTLEMENT
LOW RATE

CITY OF OCEANSIDE/E.P.A.

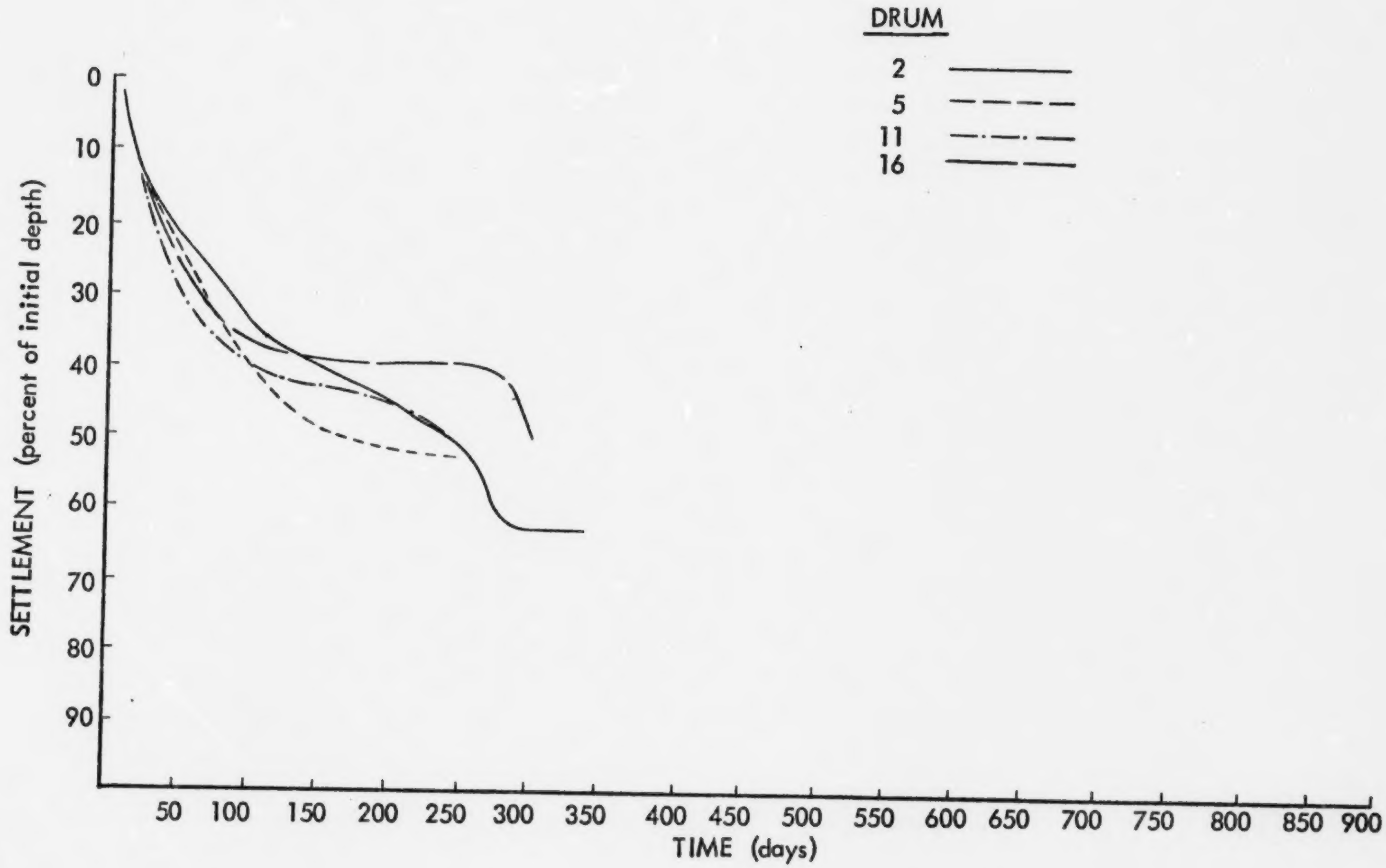


FIGURE VI-11

PILOT TEST DRUM
COMPACTION/SETTLEMENT
LOW RATE

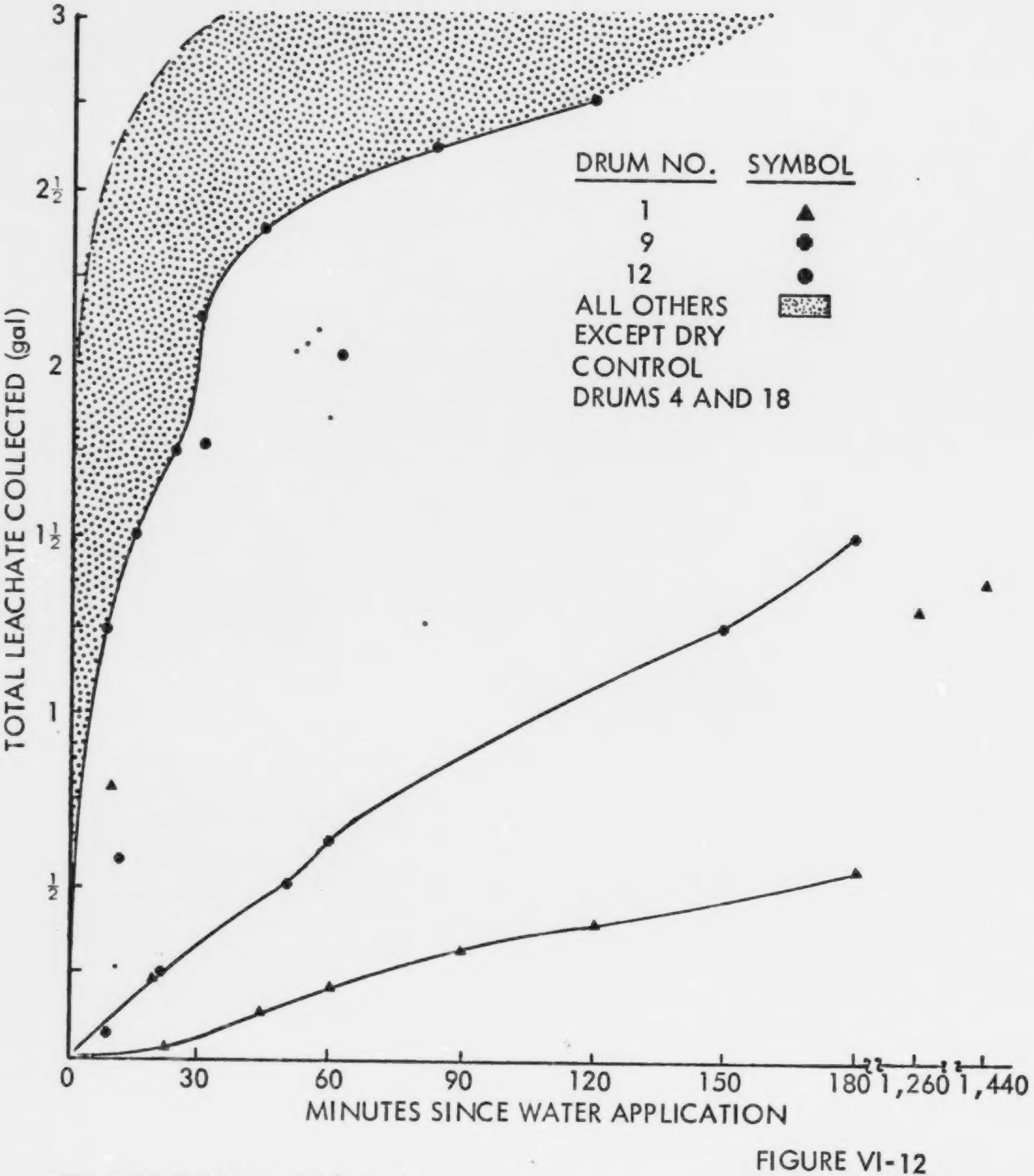
measured following the application of 3 gallons of water to each test drum. Some additional permeability tests were completed in March and from July through September, 1972. The results are presented in Figure VI-12. As expected, Drum 1, which had the highest initial density (greatest compaction), showed a far lower permeability than each of the other drums. In the case of Drum 9, however, the low observed permeability may be attributed to a relatively impervious zone around the vicinity of the drain hole. With the exception of Drums 1 and 9, all drums exhibited similar permeabilities, except that the data varied more widely at each succeeding test.

5. Temperature. Plots of temperature trends are presented in Figures VI-13 through VI-16. The data are grouped by similarity and presented as envelopes, which are compared with ambient temperatures taken at the same hours as the drum temperatures. In general, the variation in temperature closely followed that of ambient air. The bands in Figures VI-13 through VI-16 represent only the best approximation of weekly temperature data, but in part at least reflect temperature conditions of a day or two prior to the time of measurement. The temperature peaks occurring in late October and early November 1971 each coincide with short periods of exceptionally hot days, as verified by the U. S. Weather Bureau. Some of the variation between drums is attributed to the fraction of the day during which different drums were shaded by a building, and the extent to which some were shielded from the wind by the building and each other.

Ambient temperatures were only intermittently recorded, but were always below the temperatures of solid waste in the drums. In all cases, the temperatures were taken between mid-morning and 6:00 P.M. The daytime air temperature in a closed but empty drum, comparable in size to those filled with solid waste, was also observed intermittently, and was invariably well above that of the solid waste in the other drums. Since this drum was subject to the same wind and sun conditions as the others, the observation is of value to indicate that the temperature rise may be attributed to rapid solar heating of air in the drums with no detectable contributions from bacterial action.

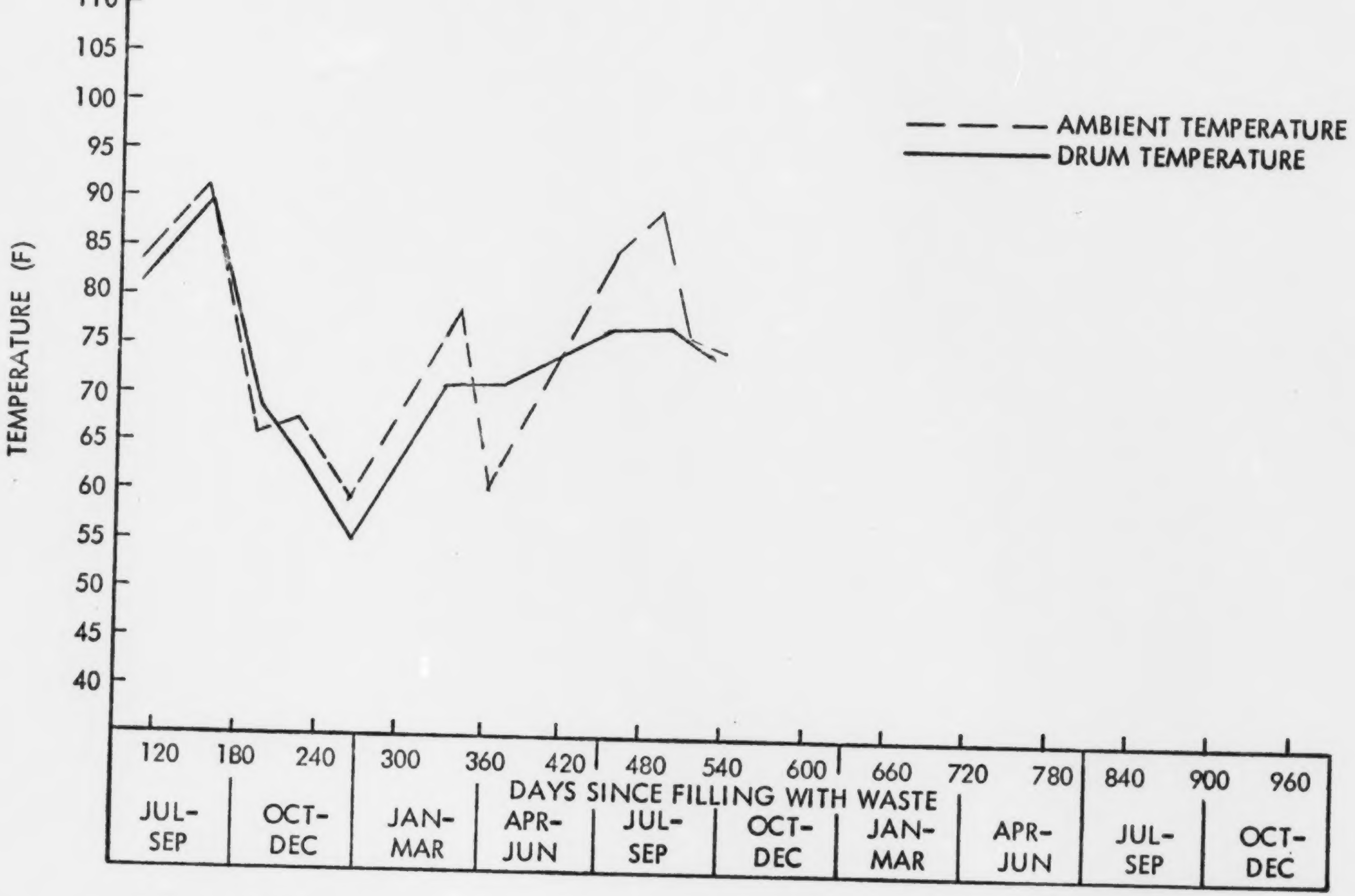
Under the conditions of the experiments, any temperature rise due to bacterial action would be limited because of the relatively higher rates of heat transfer between the drums and their surroundings through radiation and convection. In one instance, during sampling in the upper part of the contents of Drum 1, wisps of steam were seen. However, this was a local phenomenon presumably occurring only in relatively small pockets, so the heat generated was distributed through the contents of the drums with a negligible overall temperature rise.

The test drums are not thermally analogous to any landfill conditions, because of their high surface to volume ratio and short (1 ft) minimum path for heat conduction to the outside. The same solid waste and sludge buried in a landfill would be better insulated and less affected by sun, wind or ambient air temperatures and the heat generated could result in higher temperatures.



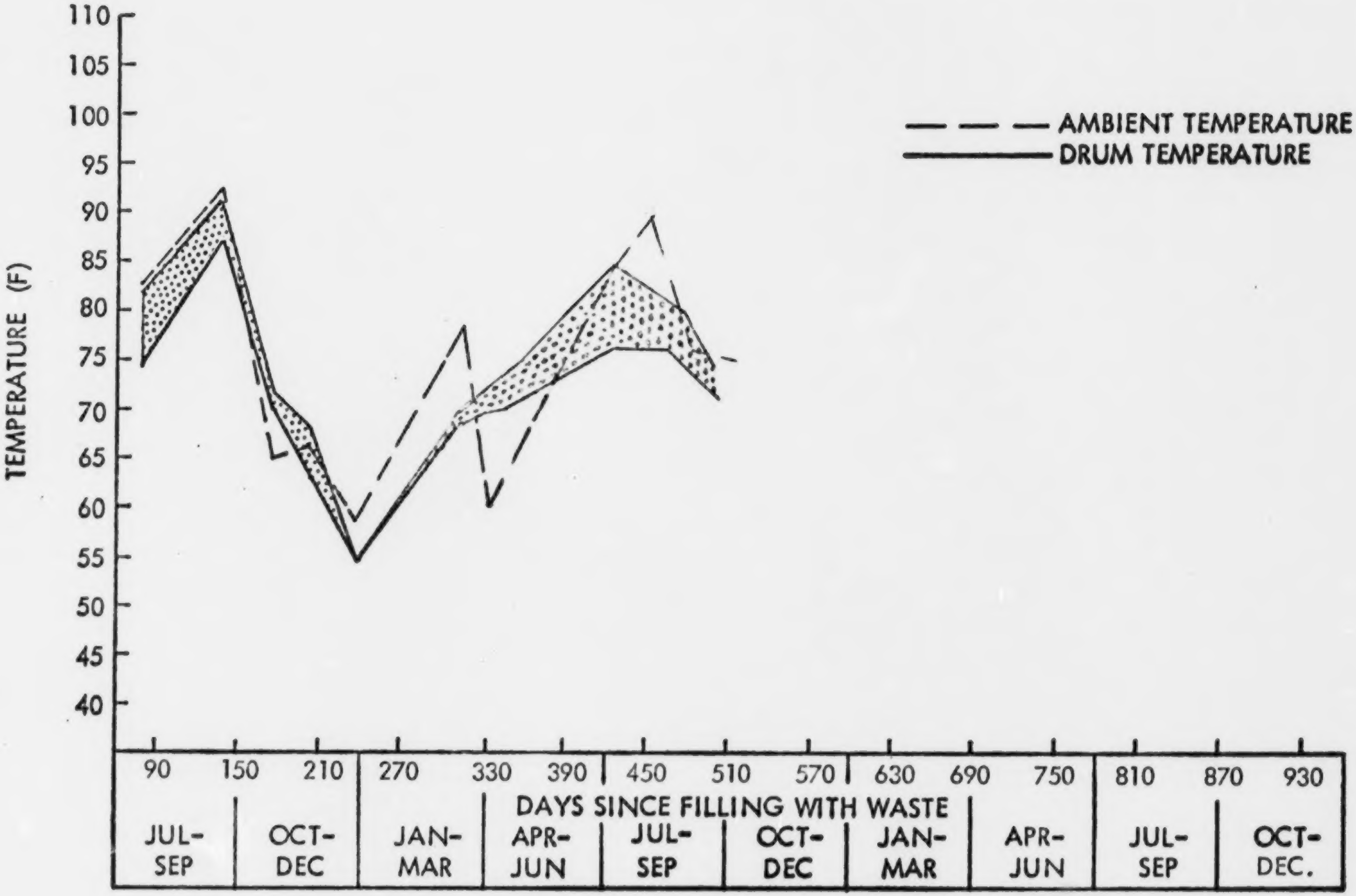
CITY OF OCEANSIDE/E.P.A.

FIGURE VI-12
LEACHATE FLOW RATES



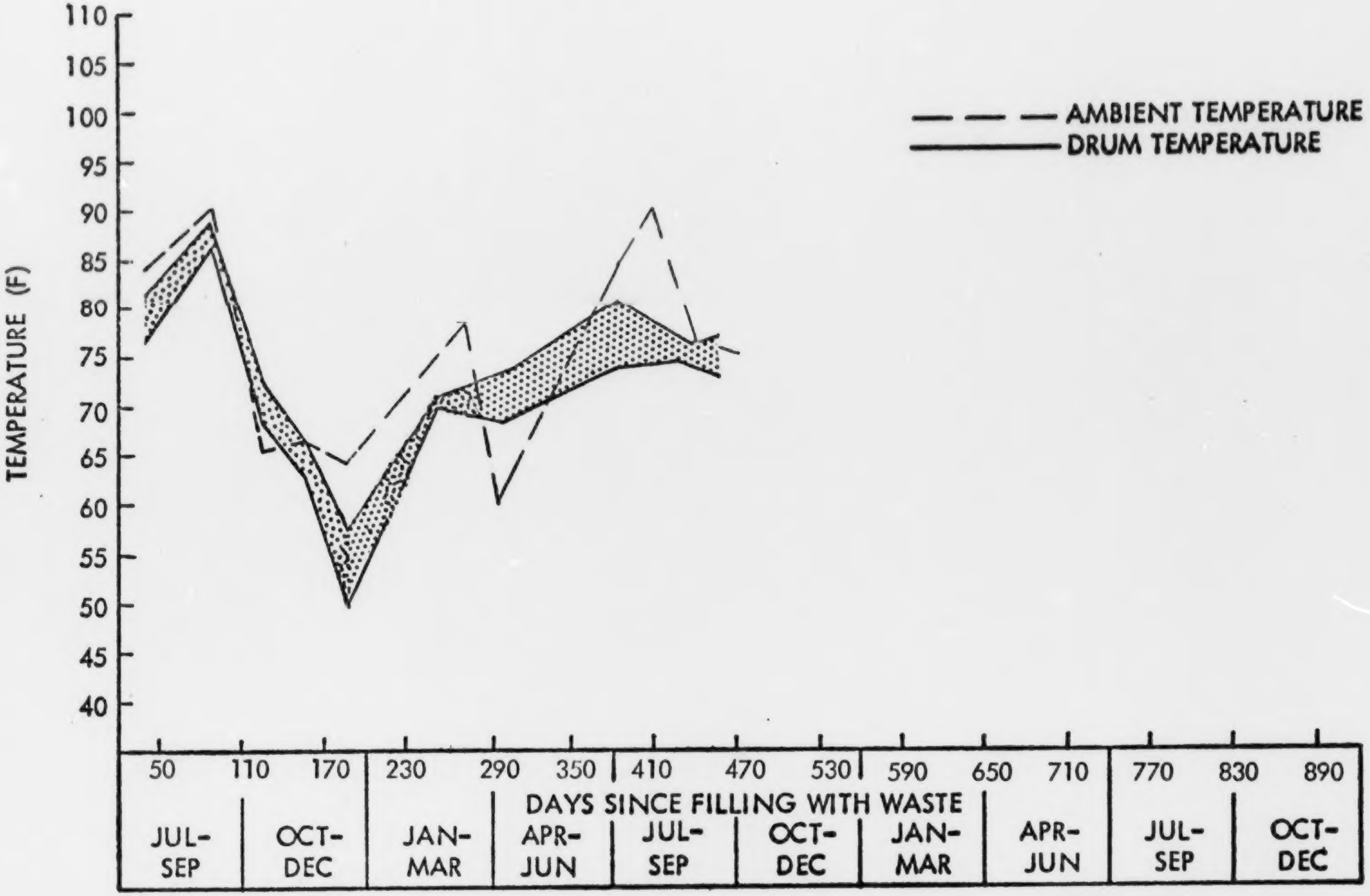
CITY OF OCEANSIDE/E.P.A.

FIGURE VI-13
TEST DRUM 1
TEMPERATURE-TIME CURVE



CITY OF OCEANSIDE/E.P.A.

FIGURE VI-14
TEST DRUMS 2, 3, 4, 5
TEMPERATURE-TIME CURVE

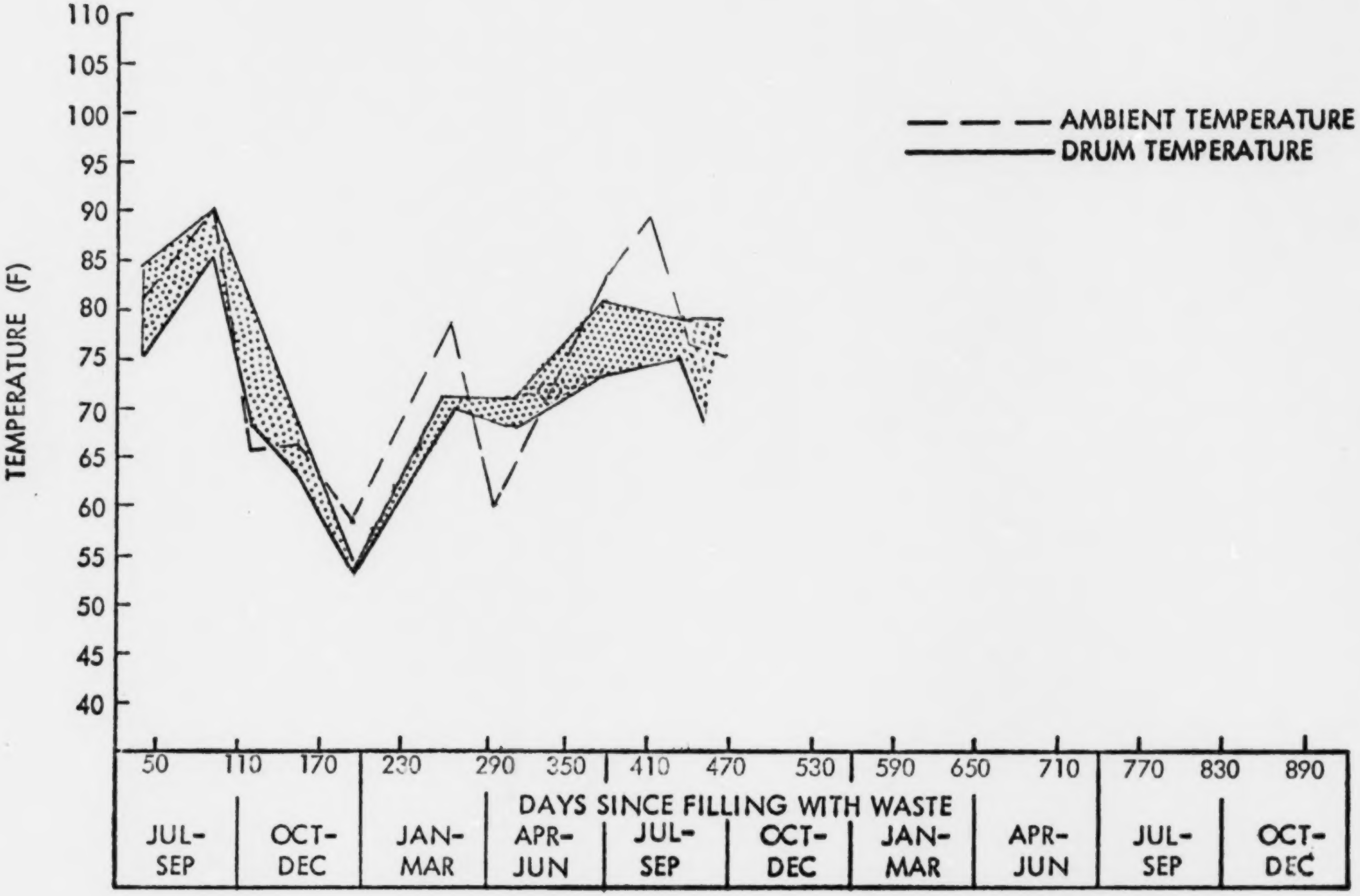


CITY OF OCEANSIDE/E.P.A.

FIGURE VI-15

TEST DRUMS 7, 8, 9, 14, 15, 17, 18

TEMPERATURE-TIME CURVE



CITY OF OCEANSIDE/E.P.A.

FIGURE VI- 16
TEST DRUMS 6, 10, 11, 12, 13, 16
TEMPERATURE-TIME CURVE

6. Qualitative and Other Miscellaneous Observations. When the drums were periodically opened for compaction and water addition, they were inspected for odor, insects, and mold growths. The results are summarized as follows.

a. Odor. Odors followed a predictable pattern. Drums filled only with solid waste rapidly developed the characteristic rotting garbage smell associated with landfills. Odors lessened as drying occurred in Drums 4 and 18, which were the dry controls, and were intensified in Drum 17 by the application of water. In most other drums, this scent was not quite masked by the characteristic septic sulfide smell of the sludges applied to them. The strongest and most noxious initial odors were from Drums 10 and 11, to which raw primary sewage sludge was applied. This scent of septic sewage sludge was identifiable as a separate component, and the intensity was sufficient to mask the garbage scent from these two drums. This scent was even detectable for several days in the first few samples of leachate collected from Drum 11, which had its solid waste saturated with raw primary sludge. Drum 10, which had received 0.61 lb of sludge per lb of solid waste (wet weight) had less odor.

During the first 90 to 110 days after the initial sludge or water applications, the odors from all of the drums remained relatively intense and became increasingly similar. After 130 to 170 days, however, the odor in the drums, with one exception, was greatly reduced and was not very unpleasant. This final odor could best be described as a barnyard or compost heap "earthy" odor, similar to wet leaves and dirt. After 150 to 205 days, all the pilot drum odors were very weak and of the earthy or compost type.

The odors of leachates more or less paralleled those observed in the drums, although their evolution to the final earthy type scent progressed slightly faster. While the solid waste initially released essentially the same scent as a conventional landfill, the comparison fails with regard to leachates. Natural leachates, obtained from the Oceanside municipal landfill and from the test cells described in Chapter VII, had a characteristic putrid scent similar to acetic acid that was more sour, stronger, and much more unpleasant than that observed from the drum leachates.

b. Molds and Plant Growths. Molds were the first surface growth observed on the solid waste; they occurred in Drum 1 (saturated mixed sludges) within the first month after applying sewage sludge. The molds developed a bright red color and grew profusely over a two week period until they covered about 30 percent of the surface area of the waste in the drum. The mold color changed to grey and the mold diminished until a second cycle of growth started at the end of the third month. The color became white and the mold surface growth continued in Drum 1 until the end of the seventh month after which no growths were observed through month 12. No mold growths were observed at any time in Drums 4 (dry control), and Drums 6 and 7 (digested La Salina sewage sludge). Molds were observed in the other drums on one or at most, two occasions during the first 11 months. After the first year, few molds were observed in any of the drums.

Small plant growths were observed in Drums 3, 8, 11, 13, and 16 on one occasion each during the first 11 months, and in Drum 8 on two occasions. Only small sprouts developed less than 1/16 inch in height.

c. Flies, Ants, and Other Insects. Flies, spiders, ants, and a few other insects were observed on the pilot drum surfaces at various times during the first 12 months; of these, flies were by far the most numerous and were observed in every drum. The flies observed were small and resembled fruit flies; 24 specimens were obtained and identified* as follows:

Family SCATOPSIDAE, The Minute Black Scavengers, seven specimens: Small, shiny, black flies. Breed in decaying vegetable and animal matter and excrement. "They often breed in sewers and privies and frequently become very numerous in houses, where they cause more anxiety than harm."

Family MYCETOPHILIDAE, The Fungus Gnats, nine specimens: "Moderately small, brown, elongated coxae (basal segment of leg)." Breed in "soil, wood, fungi, probably feeding on fungus growth." "Adults are found in moist places, especially about decaying wood. . .moist humus and prefers dark places." Often a pest in houses after fertilizing lawns.

Family PSYCHODIDAE, The Moth Fly or Filter Fly, seven specimens: Smallest of specimens submitted. Light brown. "Thickly haired small flies, wings covered with hairs on sides and folds web-like over the back." Presence of adults in homes indicated breeding in drain pipes or nearby septic condition.

Larva Diptera; Suborder Cyclorrahapha, 1 specimen: Division--Schizophora; Section--Acalyptrate; probably a member of the Family Drosophididae.

7. Production of Leachate Constituents. The quantities of leachate constituents that leached from the pilot test drums per lb of dry solid waste and sludge solid are given in Tables VI-14 to VI-17. No consistent pattern is evident between different drums that might be related to the type or quantity of sludge added, or the quantity of water added.

The cumulative quantity of water added per lb of dry solid waste plus sludge solids up to the day when BOD_5 became negligible (less than 60 mg/l) were as given on Table VI-18. The wet control Drum 17 required a high quantity of water and the next longest time before BOD_5 appeared to stabilize at negligible values. The cause of the long time for Drum 12 to stabilize is unknown. The aerated Drums 14 and 15 received larger applications of water and required less time to stabilize their BOD_5 than the other drums.

---

*The identification of flies was made by Mr. Harvey I. Magy, Southern California Area Representative, California State Department of Public Health, Bureau of Vector Control and Solid Waste Management, Los Angeles, California. Quotations were taken from Curran, C.H., The families and genera of North American diptera, The Ballan Press, New York, 1934.

TABLE VI-14

TOTAL BOD_5 IN TEST DRUM LEACHATES DURING 1971

	Quantity, lbs BOD_5 per lb dry wt solid waste (plus sludge solids where applicable)		
Drum	Days since filling	Equivalent rainfall, in.	BOD_5* $\times 10^{-3}$
1	265	52.4	2.66
2	183	35.8	3.37
3	198	41.6	2.95
5	218	41.1	1.55
6	175	41.1	4.16
7	188	51.8	3.30
8	169	47.6	9.24
9	155	58.2	6.88
10	306	40.5	11.1
11	171	45.8	6.37
12	221	58.4	1.01
13	165	52.2	8.25
14	138	35.1	4.31
15	124	35.7	9.21
16	109	31.0	3.75
17	153	38.1	7.80

* Fresh and residual leachate BOD_5 were added in weighted proportion to the volumetric quantity of each obtained from the test drums.

TABLE VI-15

TOTAL METALS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES DURING 1971-72

			Quantity, lbs metals per lb dry wt solid waste (plus sludge solids where applicable)		
Drum	Days after filling	Equivalent rainfall, in.	Mg $\times 10^{-4}$	Fe $\times 10^{-6}$	Zn $\times 10^{-6}$
1	450	64.3	1.46	3.19	6.24
2	424	61.3	1.33	8.54	6.17
3	424	66.0	1.59	5.39	2.84
5	424	60.1	1.63	4.15	4.34
6	381	60.1	1.48	3.33	6.36
7	379	66.0	1.83	4.67	2.74
8	375	66.6	1.83	4.07	2.92
9	375	67.2	2.04	6.17	3.74
10	375	61.6	1.63	4.58	4.76
11	375	66.0	2.10	14.21	3.42
12	384	66.6	0.92	5.03	5.15
13	384	66.0	1.72	3.95	2.86
14	383	61.3	1.39	3.74	4.81
15	373	66.6	0.90	5.38	6.20
16	360	62.5	1.55	9.25	11.70
17	379	66.0	1.67	5.63	7.35

TABLE VI-16
TOTAL CONSTITUENTS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES DURING 1971

Drum	Days after filling	Equivalent rainfall, in.	Quantity, lbs constituents per lb dry wt solid waste (plus sludge solids where applicable)					
			SO_4 × 10^{-4}	PO_4 × 10^{-6}	NO_3 × 10^{-6}	Cl × 10^{-3}	Ca × 10^{-4}	N × 10^{-4}
1	260	52.4	6.33	8.80	1.92	1.86	4.40	2.99
2	234	49.4	15.40	11.20	5.82	2.14	2.46	5.03
3	234	54.1	1.71	9.75	10.00	2.27	6.95	6.83
5	234	48.2	2.24	7.13	285.00	1.85	8.45	6.32
6	191	48.2	7.27	5.82	7.25	1.46	9.83	7.80
7	189	54.1	5.31	6.05	1.33	2.25	2.90	8.70
8	185	54.7	7.07	5.49	9.14	2.09	6.58	9.63
9	185	55.3	3.26	2.42	280.00	2.07	1.51	2.06
10	195	49.7	3.11	11.10	21.30	2.28	1.07	1.05
11	195	54.1	~0	1.45	1.16	1.0	1.05	1.82
12	195	54.7	1.45	0.97	2.62	2.15	0.63	7.26
13	194	54.1	7.14	0.95	1.53	2.00	1.04	3.10
14	193	49.4	2.06	1.03	3.00	1.71	1.46	3.19
15	198	54.7	5.95	1.19	1.29	1.04	0.39	5.47
16	170	50.6	5.06	0.57	22.90	2.02	0.56	5.75
17	189	54.1	2.69	0.86	19.1	1.55	1.01	5.05

TABLE VI-17
TOTAL METALS IN TEST DRUM LEACHATES
COMPOSITE SAMPLES DURING 1971

			Quantity, lbs metals per lb dry wt solid waste (plus sludge solids where applicable)					
Drum	Days after filling	Equivalent rainfall, in.	Mg $\times 10^{-4}$	Fe $\times 10^{-6}$	Zn $\times 10^{-6}$	Cu $\times 10^{-5}$	Ba $\times 10^{-3}$	F $\times 10^{-6}$
1	260	52.4	1.32	0.615	5.28	1.41	1.23	1.68
2	234	49.4	1.31	1.34	5.94	1.85	1.68	~ 0
3	234	54.1	1.49	1.95	2.44	2.26	2.14	~ 0
5	234	48.2	1.49	0.71	3.06	1.99	1.63	~ 0
6	191	48.2	1.27	0.53	5.88	1.60	1.60	~ 0
7	189	54.1	1.72	1.92	2.42	1.81	2.06	~ 0
8	185	54.7	1.73	1.95	2.44	1.95	1.65	~ 0
9	185	55.3	1.82	1.45	3.02	1.81	1.94	2.3
10	195	49.7	1.57	1.78	4.44	1.78	1.78	1.22
11	195	54.1	1.86	1.21	3.02	1.70	1.82	4.12
12	195	54.7	0.72	1.81	2.42	1.39	1.63	2.30
13	194	54.1	1.61	0.83	2.38	1.90	1.67	5.24
14	193	49.4	1.25	0.51	2.06	1.70	1.55	1.44
15	198	54.7	0.73	2.16	2.98	2.68	1.67	1.18
16	170	50.6	1.39	2.30	5.75	2.36	1.90	~ 0
17	189	54.1	1.47	1.97	3.69	2.40	2.15	~ 0

TABLE VI-18

QUANTITY OF WATER ADDED TO DRUMS TO COMPLETE BIO-OXIDATION

Drum	Days to BOD_5 less than 60 mg/l	Water addition lb water per lb dry solid waste and sludge solids
1	360	10
2	300	10
3	300	12
5	360	12
6	360	11.5
7	360	13.5
8	360	13
9	300	12
10	360	12
11	360	13
12	500	13.5
13	360	12.5
14	300	14
15	300	14.7
16	300	14.5
17	400	14.5

A comparison of Table VI-14 with VI-18 indicates no relationship between total BOD_5 produced and the quantity of water added or the number of days passed until BOD_5 stabilized at reasonably low values (60 ± mg/l).

8. Comparative Summary of Test Drum Parameters. The following discussion summarizes variations in parameters between the control test drums and drums receiving sewage sludge and septic tank pumpings. The control test drums and conditions are as follows (see Table VI-3):

Drum	Condition
4	Dry control with single water application
17	Water applied–no sludge
18	Dry control - no water applied

a. Leachate Generation. Control Drum 17 absorbed 1.75 lb of water per 1.0 lb dry weight solid waste to saturation. This absorption capacity for water fill is about the average lb per lb saturation levels of the drums receiving sewage sludge and septic tank pumpings. It appears, therefore, that the water absorption capacity is a valid indicator of liquid sewage sludge absorption capacity in solid waste.

Test drum water retention (Table VI-6) indicated that Control Drum 17 retained about the average for drums receiving sludge and septic tank pumpings. It would appear that sludge solids do not effect the moisture holding capacity of solid waste.

b. Leachate Characteristics. Again, Drum 17, being a wet control, was the only control that produced leachate.

The BOD5 of leachate from Drum 17 followed the general trend indicated by the average value line shown in Figure VI-3. The maximum BOD_5 in Drum 17 was 3500 mg/l, which occurred 40 days after initial water application; this peak coincided in time with BOD5 peaks of the other drums receiving sludge and septic tank pumpings. The Drum 17 BOD5 maximum was exceeded only by Drums 13 (digested primary sludge) and 15 (digested activated sludge, mechanically aerated). A comparison of total BOD_5 removed from drums receiving sewage sludge, septic tank pumpings, and water only is given in Table VI-19. The quantity of BOD5 removed from the water control Drum 17 per lb of dry solid waste was more than double the quantity of BOD_5 removed from the drums receiving sludge and septic tank pumpings. The weight of dry sludge solids added to Drums 3 and 7 are not sufficient to account for the greater quantity of BOD_5 removed from Drum 17. Drum 17 did require a longer time and more water additions to remove the BOD_5 (see Table VI-14), but this only indicates the above results.

TABLE VI-19

TOTAL BOD$_5$ IN TEST DRUM LEACHATES COMPOSITE SAMPLES DURING 1972

	Quantity, lbs BOD$_5$ per lb dry wt solid waste (plus sludge solids where applicable)		
Drum	Days since filling	Equivalent rainfall, in.	BOD$_5$ x 10^{-3}
3 *	149	30.4	3.14
	198	41.6	2.95
	239	54.1	2.20
	540	68.5	2.11
7$^+$	105	29.2	3.39
	188	51.8	3.30
	301	60.2	2.96
	496	68.4	2.77
17#	104	29.2	7.95
	153	38.1	7.80
	193	54.1	7.04
	483	64.9	6.93

* Domestic septic tank pumpings.

+ Digested activated sludge.

# Water only.

Turbidity, color, conductivity and total dissolved salts of Drum 17 leachate showed no variation from trends followed by other drums.

The Drum 17 pH ranged between 6.3 and 7.2 (0.9 units), whereas the pH in other drums ranged from 5 to 8.6 (1.5 or greater units), Drum 17 pH indicated the smallest variation and the second highest average (6.9) pH values. Drums 6 and 7 exhibited average pH values of about 7.1 (both received digested activated sludge). Apparently, the addition of sludge to solid waste generally produced a more acidic leachate, which varied over a wider range of acidic values than might be expected from a normal solid waste landfill. This stable pH characteristic was also observed in leachate from the old Oceanside landfill (pH 5.1 to 5.2) as compared to the leachate from test cell 1 (pH 4.6 to 5.9) (see Table VI-7). The Oceanside landfill and test cell pH values were, however, much more acidic than the test drum pH; this probably reflects the highly anaerobic fill and lack of leachate dilution whereas the test drums were somewhat aerated and there was a higher pH (8.4) in the water added.

A comparison of "fresh" and "residual" leachates (Table VI-8) and chemical analyses of 1971 leachate composites (Table VI-10) indicates that Drum 17 corresponded to many of the drums with sludge. Due to wide variations in data, no conclusive trend is apparent.

c. Gas Generation. Gas analyses presented in Table VI-13 indicate concentrations of CO_2 and CH_4 that fall in the low end of the range of concentrations for all of the drums. The gas sampling is not considered accurate enough, however, to indicate significant differences between individual drums.

d. Settlement Settlement curves (Figures VI-7 to VI-11) indicate that settlement in Drums 4 and 18 (dry controls) followed nearly identical trends, and had settled about 60 percent within the first year. Drum 17 also was similar in settlement after one year, (63 percent), but showed a higher rate during the first half-year (60 percent) and then levelled off (3 percent during the second half-year period). The three control drum settlement rates did not vary from the settlement rates observed in the majority of drums receiving sludge.

e. Other Observations. Temperature, odor, mold, fungi, and plant growths, in the control drums followed the same trend and values as in the other drums. Drum 17 contained the greatest number and frequency of fly counts. It is hypothesized that the flies preferred Drum 17 due to the presence of food particles that were not contaminated with sewage sludge.

f. Summary. It appears from the above discussion that the major effect of disposing sewage sludge or septic tank pumpings into solid waste consists of lowering and causing wider variations in the pH of resulting leachates. Since CO_2 tends to lower the pH of water when its concentration in water increases, the generally lower CO_2 in the gas analysis for the control drums would indicate a relatively higher pH should be expected. If higher rates of bio-oxidation result from admixing sludge with solid waste, then the pH of the leachate and CO_2 in the gas analyses would provide a good indication of these effects. Also, a somewhat lower pH might be expected in normal solid waste landfills without admixed sludge or septic tank pumpings due to the lower pH of rain water (7.0) as compared to the tap water used in the test drums (pH=8.4).

VII. SIMULATION OF SANITARY LANDFILL IN FIELD TEST CELLS

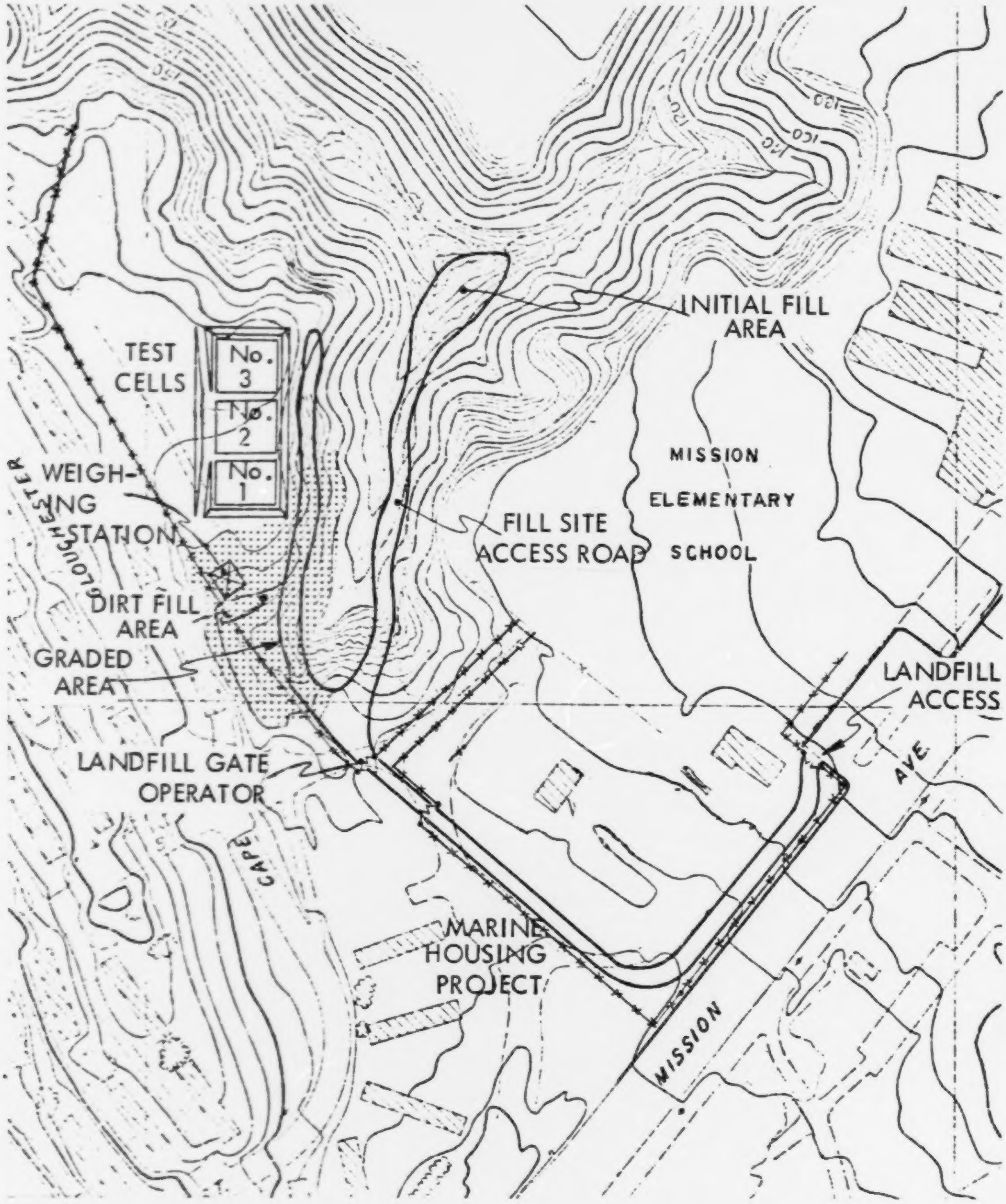
A. Purpose

In order to evaluate the disposal of liquid sludge to a landfill under large-scale controlled conditions, three test cells (described below) were constructed in the City of Oceanside at the new municipal landfill site. These test cells were built so that they permit evaluation of such parameters as landfill settlement, waste decomposition, gas generation, leachate flow, equipment operation, odor development, and attraction of vermin, birds, etc. The test cells have been under observation since filling in February 1972. This chapter presents a general description of the test cells and discusses the preliminary results obtained to date. The monitoring of the test cells is expected to continue through the one year of the remaining program.

B. Method of Study

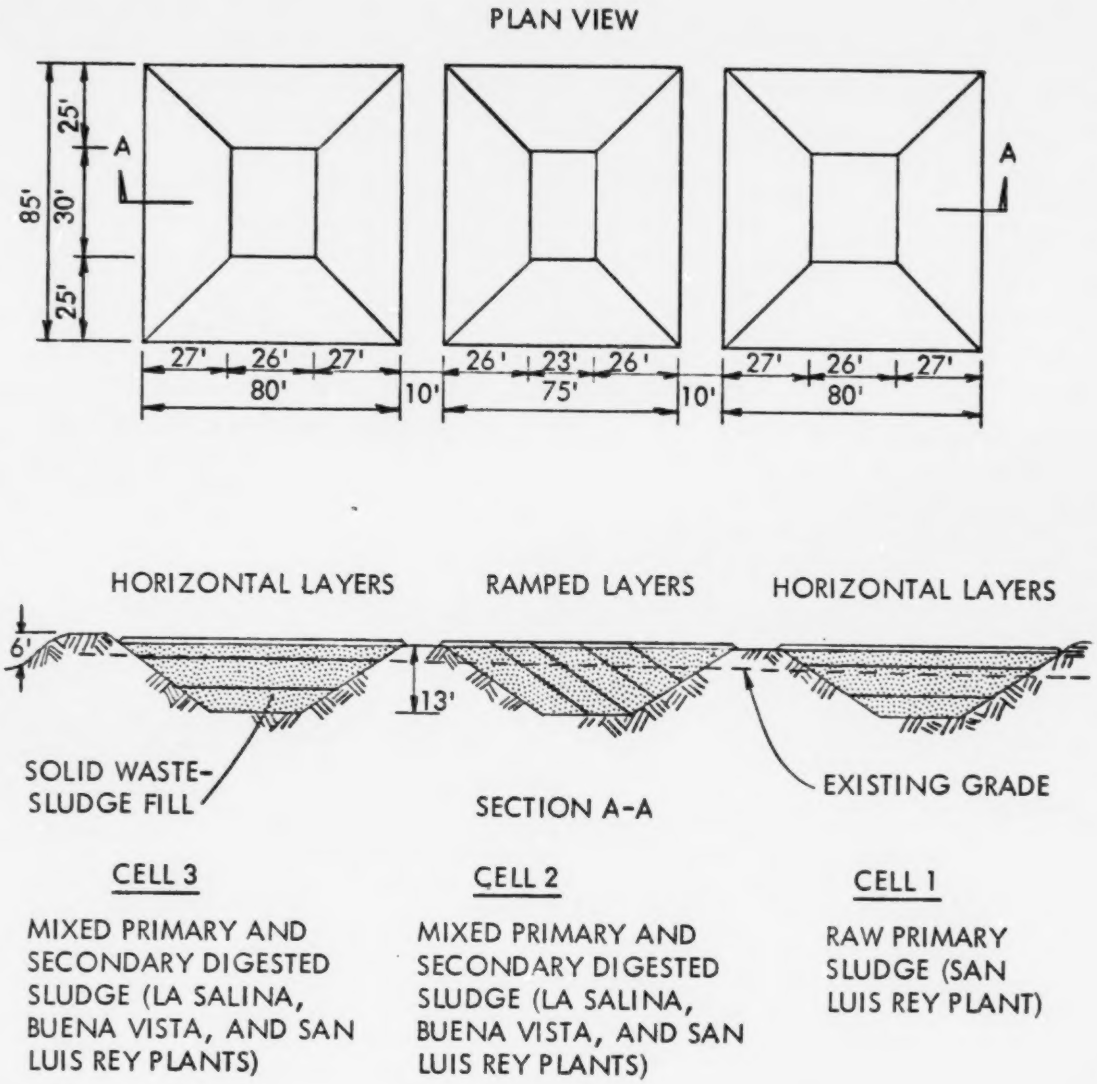
1. Site Location. The three test cells were constructed adjacent to the new municipal sanitary landfill site that opened November 15, 1971. The landfill site plan noting location of the three test cells is shown on Figure VII-1. The test cells are about 50 feet north of the landfill access road on the rim of the fill canyon. The cells are within observation range of the landfill operator (80 feet) and yet distant enough from the landfill access road traffic so as to remain undisturbed by daily activities. The land area underlying the three test cells is stable and the surrounding surface area has a one to two percent grade sloping away from the test cells, thus minimizing the effects of external drainage. The site is in an exposed position to wind and other normal local weather conditions. It is accessible for routine monitoring.

2. Cell Design Configuration. Figure VII-2 presents the approximate dimensions of the three test cells. The cells (numbered 1, 2, and 3) are located adjacent to each other so as to utilize a common berm between them. Each cell holds solid waste and sewage sludge in volumes equal to the total quantities of each produced in the City during a one-week period. Each cell bottom and side wall is lined with a continuous 10-mil polyethylene membrane with an 8-inch sandy soil overlay to protect the membrane from damage during waste filling. The membrane and cell construction details are shown in Figure VII-3 and Photograph VII-1. A porous sump is installed to accumulate the leachate. The collected leachate is removed through a 1-inch diameter polyvinyl chloride (PVC) drain pipe which extends through the wall of the test cell and is equipped with a valve at its outer end. Air cannot enter through the drain. A concrete valve box is installed over each leachate drain valve to prevent disturbance of the equipment. The leachate collection system is shown in Photograph VII-2.


TEST CELLS
No. 3
No. 2
No. 1
WEIGHING STATION
GLOUCHESTER
DIRT FILL AREA
GRADED AREA
LANDFILL GATE OPERATOR
CAPE
MARINE HOUSING PROJECT
FILL SITE ACCESS ROAD
INITIAL FILL AREA
MISSION ELEMENTARY SCHOOL
LANDFILL ACCESS
MISSION
AVE
120

CITY OF OCEANSIDE/E.P.A.

FIGURE VII-1
LOCATION OF TEST CELLS


PLAN VIEW
85'
25'
30'
25'
A
A
27'
26'
27'
80'
10'
26'
23'
26'
75'
10'
27'
26'
27'
80'
HORIZONTAL LAYERS
RAMPED LAYERS
HORIZONTAL LAYERS
6'
13'
SOLID WASTE-SLUDGE FILL
SECTION A-A
EXISTING GRADE
CELL 3
MIXED PRIMARY AND SECONDARY DIGESTED SLUDGE (LA SALINA, BUENA VISTA, AND SAN LUIS REY PLANTS)
CELL 2
MIXED PRIMARY AND SECONDARY DIGESTED SLUDGE (LA SALINA, BUENA VISTA, AND SAN LUIS REY PLANTS)
CELL 1
RAW PRIMARY SLUDGE (SAN LUIS REY PLANT)

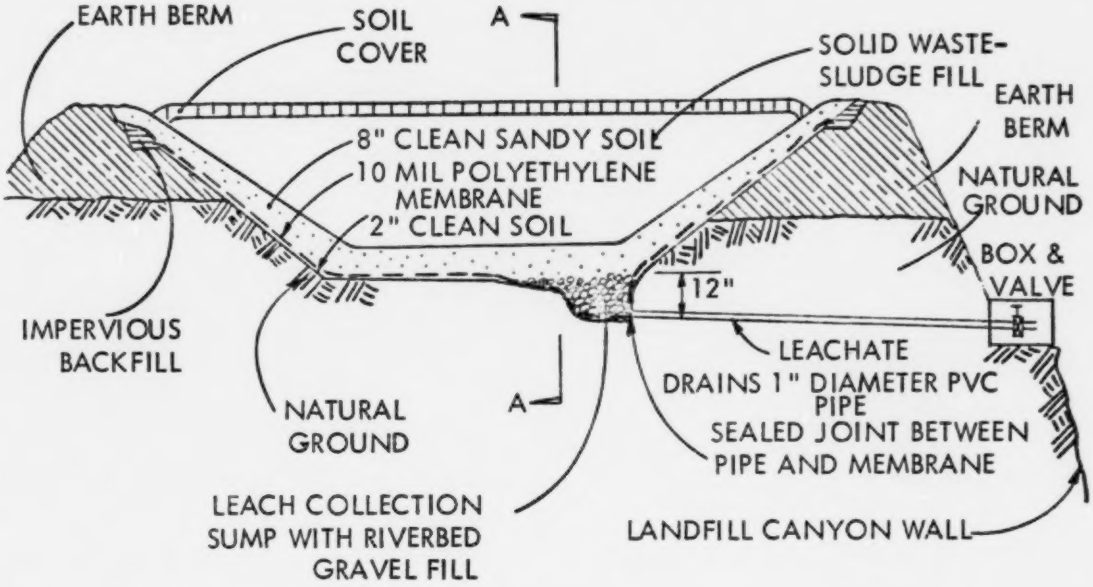
NO SCALE. LINEAR DIMENSIONS SHOWN ARE APPROXIMATE AND VARY ± 5 FEET BETWEEN CELLS.

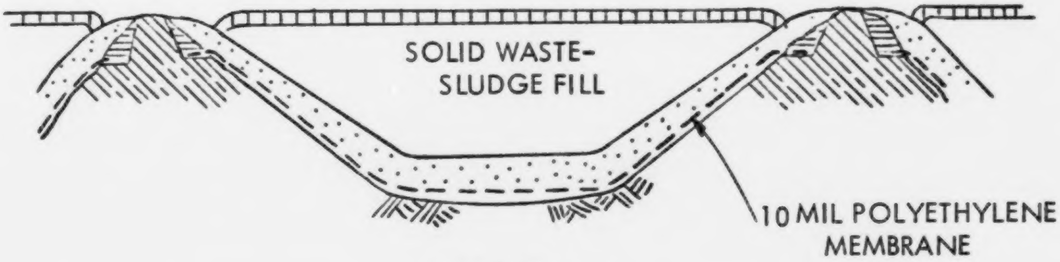
NOTE: FOR DETAILS OF CELL STRUCTURE SEE FIGURE VII-3.

CITY OF OCEANSIDE/E.P.A.

FIGURE VII-2
CELL DESIGN CONFIGURATION

TEST CELL PROFILE


EARTH BERM
SOIL COVER
A
SOLID WASTE-SLUDGE FILL
EARTH BERM
8" CLEAN SANDY SOIL
10 MIL POLYETHYLENE MEMBRANE
2" CLEAN SOIL
NATURAL GROUND
BOX & VALVE
12"
IMPERVIOUS BACKFILL
LEACHATE
DRAINS 1" DIAMETER PVC PIPE
NATURAL GROUND
A
SEALED JOINT BETWEEN PIPE AND MEMBRANE
LEACH COLLECTION SUMP WITH RIVERBED GRAVEL FILL
LANDFILL CANYON WALL


SOLID WASTE-SLUDGE FILL
10 MIL POLYETHYLENE MEMBRANE

SECTION A-A

NO SCALE.

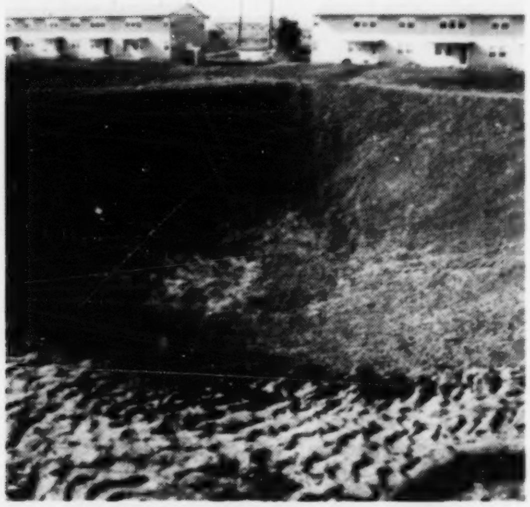
NOTE: FOR CELL DIMENSIONS, SEE FIGURE VII-2.

FIGURE VII-3
TEST CELL MEMBRANE
AND LEACHATE
COLLECTION INSTALLATIONS

CITY OF OCEANSIDE/E.P.A.

a. PLACEMENT OF TEST CELL 10-MIL POLYETHYLENE MEMBRANE LINER.

b. PROTECTIVE SOIL COVER FOR MEMBRANE LINER.



c. FINISHED GRADED TEST CELL.

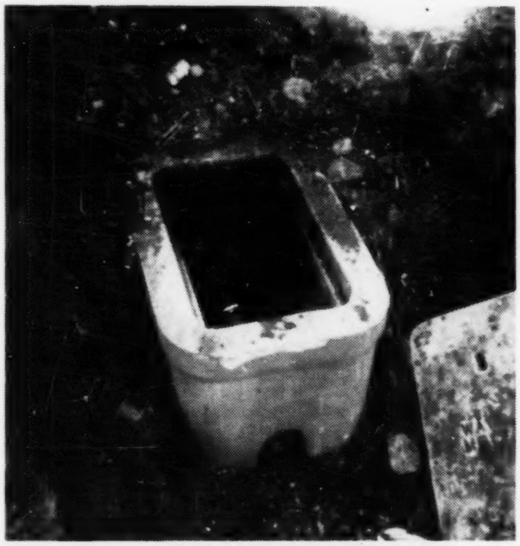
CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VII-1

FIELD TEST
CELL PREPARATION

a. LEACHATE COLLECTION SUMP.

b. LEACHATE DRAIN INSTALLATION.



c. LEACHATE SAMPLE DRAIN PIPE AND VALVE.

CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VII-2

TEST CELL LEACHATE
COLLECTION SYSTEM

3. Filling of the Test Cells. Each cell was filled with solid waste and sewage sludge over a period of seven days (Cell 1: February 9-15, 1972; Cell 2: February 3-9, 1972; Cell 3: January 26-February 2, 1972). As shown in Figure VII-2, Cell 1 was filled in horizontal layers with the application of raw primary sludge from San Luis Rey plant. Cell 2 was filled in ramped layers and Cell 3 was built up in horizontal layers each with the application of mixed primary-secondary digested sludge from the three treatment plants. The test cell filling sequence is illustrated in Photograph VII-3. The sewage sludge was admixed evenly by pumping into each cell in the ratio of one 3,500-gallon truck load for every seven solid waste collection truck loads. This one-to-seven truck load ratio is equivalent to the 1971 ratio of generation of sewage sludge to solid waste in the City of Oceanside. Two methods of sludge application are shown in Photograph VII-4. The actual quantities of solid waste and sludge placed in each cell are given in Tables VII-1, VII-2, and VII-3. The solid waste loads deposited in Cell 3 were all weighed; and the number of full truck loads deposited in Cells 1 and 2 were counted during the filling. The average weight per load deposited in Cell 3 was used to estimate the total solid waste placed in Cells 1 and 2. The filling of each cell was completed under continuous supervision to assure proper admixture of liquid sewage sludge. The average sludge to solid waste ratio was 0.6 lb per 1.0 lb (dry wt).

During filling of each cell representative daily samples of sewage sludge and solid waste were taken. A composite sludge sample was made by combining 100-ml portions of separate sludge samples in the ratio of the number of loads from the individual sludge source deposited into each cell. Table VII-4 presents partial analysis of the composite sludge samples. Random grab samples of the solid waste deposited in each cell were also taken daily. These samples were sorted into standard categories to determine their compositions. The samples were tested for moisture and organic content. Table VII-5 presents data on the in-place volumes of the waste and initial densities of the solid waste and combined sludge-solid waste for each cell.

4. Monitoring of the Test Cells. The monitoring program for the test cells included the following: a) measurement of ambient temperature, b) measurement of all temperatures at three different depths (near surface, mid-depth, and bottom--see Figure VII-4), c) analysis of gas samples from the cell bottom and from a depth of about 6 to 7½ ft. d) leachate characterization, e) settlement measurements, and f) analysis of periodic core samples from each cell. The frequency of each measurement and the agency responsible for each test are listed in Table VII-6. The placement of monitoring probes is shown in Photograph VII-5. The following is a brief description of each measurement.

a. Cell Temperature: Measurement of test cell temperatures is accomplished by lowering a glass test tube filled with water to the bottom of each temperature probe by means of a string. When the water temperature reaches a constant value, it is recorded as the cell temperature at that particular depth. (Fifteen years prior experience with all types of devices monitoring solid waste landfills has indicated that sophisticated measuring devices such as thermocouples and thermisters failed eventually in the highly corrosive landfill environment.) Temperature probes are shown in Photograph VII-6.

a. COLLECTION TRUCK UNLOADING WASTE AT START OF FILLING.

b. COMPACTING WASTE.

c. PLACING SOIL COVER ON TEST CELL.

PHOTOGRAPH VII-3

CITY OF OCEANSIDE/E.P.A.

PLACING SOLID WASTE
IN TEST CELLS

a. SPREADING PUMPED SLUDGE FROM A DOZER BLADE.

b. SPREADING PUMPED SLUDGE BY MANUAL TIE-LINE.

CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VII-4

APPLICATION OF SEWAGE
SLUDGE TO TEST CELLS

TABLE VII-1
SOLID WASTE AND SEWAGE SLUDGE PLACED IN TEST CELL 1

Waste category	Composition*	Percent dry wt	
		Moisture	Organics
Newsprint	17.7	10.4	98.0
Cardboard	4.7	6.7	98.3
Misc. paper	24.9	15.6	92.5
Food	2.5	233.0	91.0
Glass	5.0	-	-
Metals	7.9	-	-
Tree & shrub prunings	11.5	-	-
Textiles	3.9	4.9	90.0
Plastic, solid	6.4	3.5	98.5
Plastic, soft	0.3	0.0	97.5
Wood	0.9	-	-
Fines, pass a 2" sieve	14.3	11.4	50.2
Total	100.0	13.9	64.5
Sewage sludge applied:	45,500 gallons of raw primary from San Luis Rey Plant		Ratio of liquid sludge to solid waste: 0.46 lb/lb dry wt solid waste

*Total solid waste: 473 tons.

NOTE: Total dry weight of solids - 412 tons; solid waste - 407 tons; dry sludge solids - 5 tons.

TABLE VII-2
SOLID WASTE AND SEWAGE SLUDGE PLACED IN TEST CELL 2

Waste category	Composition*	Percent dry wt Moisture	Percent dry wt Organics
Newsprint	11.1	16.0	88.0
Cardboard	4.7	15.1	90.5
Misc. paper	37.9	12.5	87.5
Food	0.8	352.0	88.2
Glass	9.4	-	-
Metals	9.3	-	-
Leaves	1.1	309.0	90.2
Textiles	1.5	14.4	97.6
Plastic, solid	2.2	1.0	99.2
Plastic, soft	0.1	0.0	96.3
Fines, pass a 2" sieve	21.9	56.8	67.2
Total	100.0	26.4	64.3

Sewage sludge applied from treatment plant:			Ratio of sludge to solid waste: 0.55 lb/lb dry wt solid waste
	La Salina	17,500 gallons	
	Buena Vista	14,000 gallons	
	San Luis Rey	7,000 gallons	
	Total	38,500 gallons	

*Total solid waste: 394 tons.

NOTE: Total dry weight of solids - 299 tons; solid waste - 290 tons; dry sludge solids - 9 tons.

TABLE VII-3
SOLID WASTE AND SEWAGE SLUDGE PLACED IN TEST CELL 3

Waste category	Composition*	Percent dry wt Moisture	 Organics
Newsprint	15.3	1.1	85.6
Cardboard	3.7	15.2	87.8
Misc. paper	23.4	15.0	91.0
Food	1.2	632.0	87.0
Glass	7.2	-	-
Metals	7.8	-	-
Tree & shrub prunings	3.4	640.0	88.8
Grass	0.9	116.5	70.6
Textiles	2.1	2.3	94.5
Plastic, solid	4.0	1.8	99.0
Plastic, soft	0.1	4.7	98.1
Fines, pass a 2" sieve	30.8	10.2	26.7
Total	100.0	37.9	56.6

Sewage sludge applied from treatment plant:	La Salina	31,500 gallons	Ratio of sludge to solid waste: 0.77 lb/lb dry wt solid waste
	Buena Vista	7,000 gallons	
	San Luis Rey	17,500 gallons	
	Total	56,000 gallons	

* Total solid waste: 486 tons

NOTE: Total dry weight of solids - 312 tons; solid waste - 302 tons; dry sludge solids - 10 tons.

TABLE VII-4
ANALYSIS OF COMPOSITE SAMPLES OF SLUDGES APPLIED TO TEST CELLS*

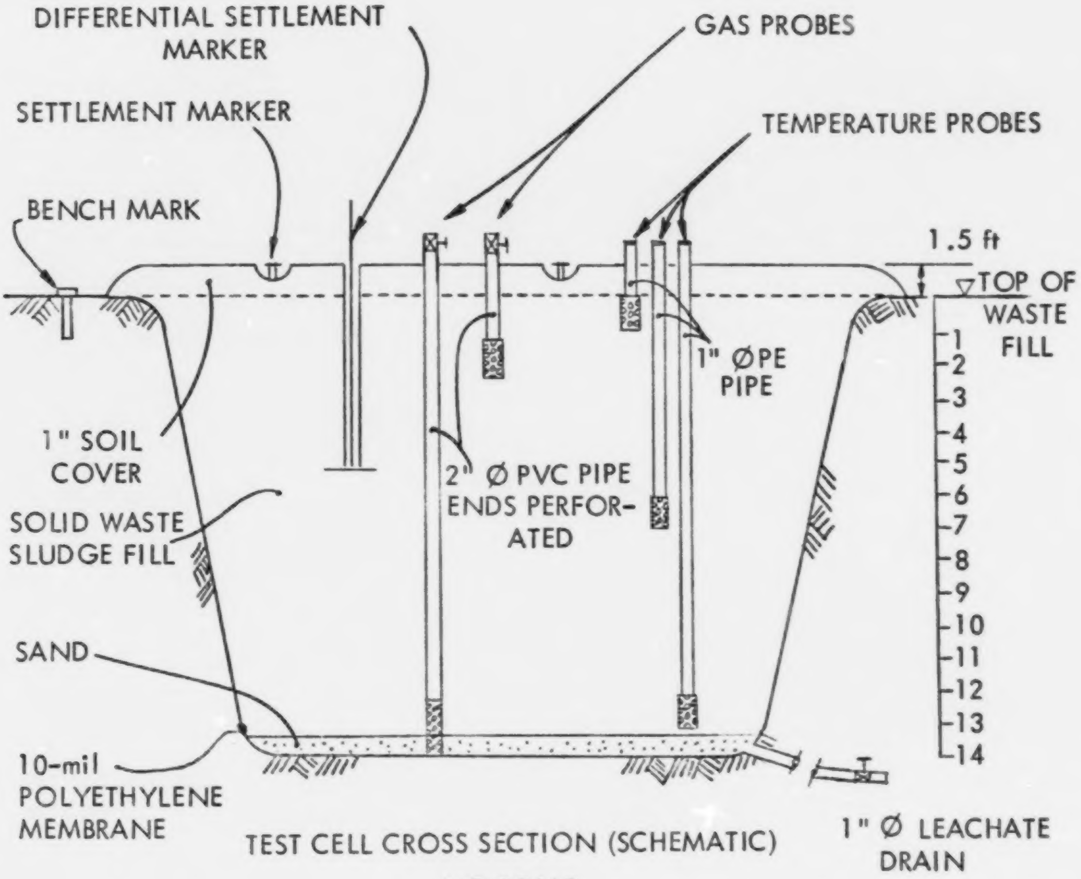
Characteristic	Test cell		
	1	2	3
pH	6.70	6.80	6.85
Electrical conductivity (micromhos/cm)	1200	1950	2300
Total solids (% wet wt)	2.48	5.45	4.42
Total organics (% dry wt)	69.7	47.8	45.2
Chloride (mg/l)	220	350	385
Phosphate (mg/l)	400	85	94
BOD_5 (mg/l)	7220	1900	4300
Organic Kjeldahl nitrogen (% dry wt)	2.2	1.06	1.20

* Analyses made on composite sample representative of all sludge added to a single test cell.

TABLE VII-5
TEST CELL IN-PLACE WASTE/SLUDGE DENSITIES

Measurement	Test Cell 1	2	3
Cell volume (cu yd)*	1,512	1,231	1,560
Density solid waste (lb/cu yd)	626	640	623
Density solid waste and sewage sludge (lb/cu yd)	876	902	923

* Excludes earth cover.


DIFFERENTIAL SETTLEMENT MARKER
GAS PROBES
SETTLEMENT MARKER
TEMPERATURE PROBES
BENCH MARK
1.5 ft
TOP OF WASTE FILL
1" ØPE PIPE
1" SOIL COVER
2" Ø PVC PIPE ENDS PERFORATED
SOLID WASTE SLUDGE FILL
SAND
10-mil POLYETHYLENE MEMBRANE
1" Ø LEACHATE DRAIN
1
2
3
4
5
6
7
8
9
10
11
12
13
14

TEST CELL CROSS SECTION (SCHEMATIC)

NO SCALE

NOTE: INSTRUMENTATION FOR THE SECOND AND THIRD YEAR LANDFILL OPERATION TESTS.

FIGURE VII-4
TEST CELL
INSTRUMENTATION

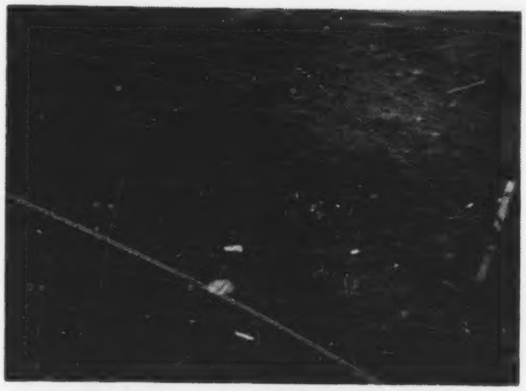
TABLE VII-6
FIELD TEST CELL MONITORING SCHEDULE

Monitoring parameter	Frequency	Performed by
Temperature	Daily - 1st month Weekly - 2nd month and after	Waste Disposal Department*
Gas sampling and analysis	Weekly - 1st Quarter Monthly - thereafter	Ralph Stone & Company, Inc.
Leachate - quantity	Weekly (or after rainfall)	Sewer Department*
Standard analyses	Weekly - 1st month Monthly - thereafter	Sewer Department*
Special analysis	Quarterly composite	Sewer Department*
Composite	Bi-yearly	Ralph Stone & Company, Inc.
Settlement measurements	Monthly	Waste Disposal Department*
Core samples of solid waste	Quarterly	Ralph Stone & Company, Inc.

*City of Oceanside municipal departments

a. PLACING CELL MONITORING PROBES.

b. CELL MONITORING PROBES IN-PLACE.

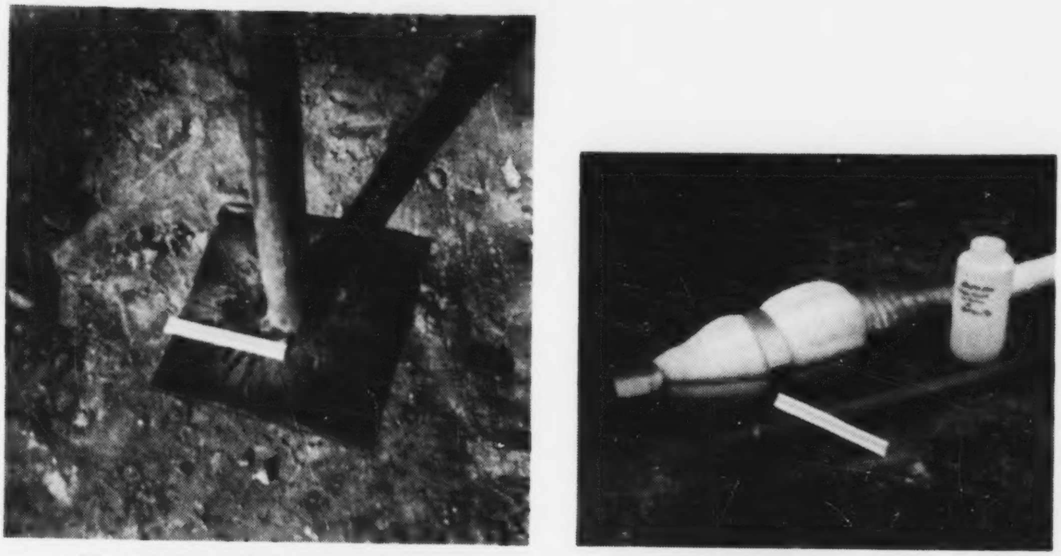


c. FINISHED CELL WITH MONITORING PROBES AND BENCH MARK.

PHOTOGRAPH VII-5

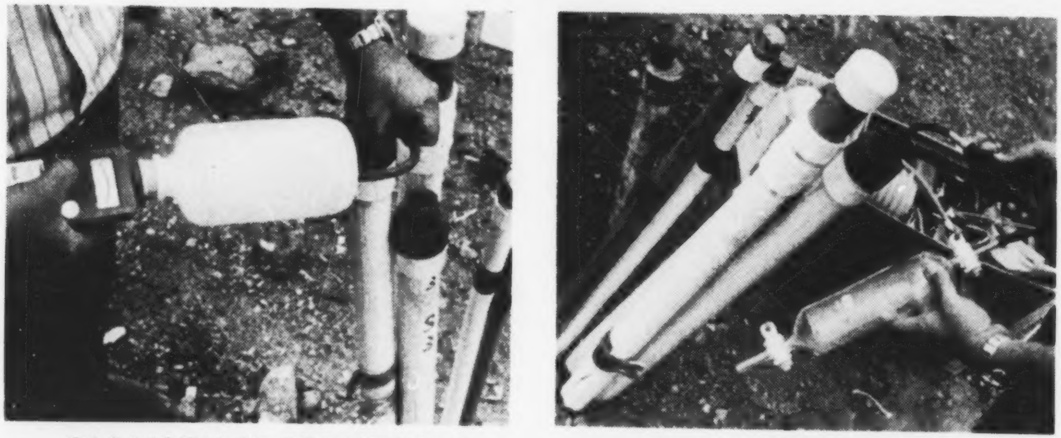
PLACING SETTLEMENT
MARKERS, TEMPERATURE
AND GAS PROBES

CITY OF OCEANSIDE/E.P.A.



a. MID-DEPTH SETTLEMENT BENCH MARK PLATE.

b. GAS AND TEMPERATURE PROBE SENSOR ENDS.



c. GAS SAMPLING FOR METHANE.

d. GAS SAMPLING FOR GAS ANALYSIS.

PHOTOGRAPH VII-6

TEST CELL
MONITORING APPARATUS

b. Gas Sampling and Analysis. The gas sampling procedure used was that developed by Ralph Stone and Company, Inc., in previous landfill studies. Basically, the procedure consists of evacuating a 250- or 500-ml sample bottle and connecting it to the test cell gas sample probe and utilizing a hand-operated suction-pressure pump. The actual equipment sequence is as follows:

gas sample probe → moisture trap → vacuum-pressure pump → gas sample bottle

Prior to sample taking, the valved probe is opened, then the probe and clean evacuated bottle is purged by passing approximately 2,500 ml of sample gas through. The bottle is then pressurized by additional pumping. Special methane and sulfide field tests were also run in-situ. The gas probes and gas sampling bottle are then resealed; Photograph VII-6 illustrates the sampling apparatus.

The gas samples were analyzed for CO_2, O_2, N_2, CH_4, and CO on a Varian Aerograph Model A90-P3 Gas Chromatograph in the Ralph Stone and Company, Inc. laboratory.

c. Leachate Characterization. The leachate sampling was as follows: when leachate had been found, the leachate valve was opened until the leachate ceased running out and began slow dripping. The leachate quantity was measured, then mixed thoroughly, and a one-quart sample was taken for chemical analysis. The refrigerated weekly/monthly samples were tested for BOD5, total dissolved solids, coliform (MPN),chlorides, nitrogen, and conductivity. The quarterly leachate samples were analyzed for heavy metals (Cr, Hg, Zn, Pb, and Cu). Composite samples, accumulated from 100-ml portions of the weekly/monthly samples from each test cell, were tested for calcium, sodium, magnesium, potassium, iron, fluoride, BOD_5, total dissolved solids, and pesticides/herbicides.

d. Settlement Measurements. Monthly surface and differential settlement measurements were made for each test cell. The test cell bench mark elevations were determined immediately after filling for base points; the bench mark elevations were then checked relative to the natural ground reference bench mark using standard surveying equipment. The bench mark plate is shown in Photograph VII-6.

5. Core Sampling and Testing. Three bore hole drillings were completed in 1972 at each test cell to obtain core samples of the soil and sludge/solid waste admixture. Care was taken to avoid drilling and puncturing the cell membrane. Core samples were taken of surface soils, and sludge/solid waste at two-foot intervals to a depth of 10 feet below the waste fill surface (about 12 feet below the cover soil surface). The bore holes were drilled a minimum of 10 feet distance from the gas and temperature probes in each test cell. Starting in the easterly quadrants, holes were drilled about 10 feet apart in successive quarters proceeding in a clockwise direction around the probes.

A 12-inch auger drill bit mounted on a 40-foot Texoma Drill Rig was used to drill the bore holes. The drilling equipment is illustrated in Photograph VII-7.

Soil, sludge/waste admixed, and solid waste samples were taken in one-quart sealed mason sample jars and returned to the Ralph Stone and Company, Inc. laboratory to determine moisture and organic content, and the remaining moisture absorption capacity. The first quarterly core samples at the 2 and 10-foot depths into the waste were taken in sterile mason jars for subsequent analyses for fecal coliform, fecal streptococci and *Psuedomonas aeruginosa*. Analytical methods used to determine the bacterial content of the core samples are described in Appendix A.

During sampling at 2-foot depth intervals, observations were made of weather, air temperature, waste temperature, odor, color, readability, appearance and biodegradability. A copy of the core sample data sheet is included in Appendix B, and sample observation procedures are described in Appendix A.

Core samples from each hole with the highest and lowest moisture contents were selected for saturation and leaching tests. The saturation and leaching methods are described in Appendix A.

C. Results and Discussion

The field test cells were placed in operation in February 1972 and have been continuously monitored at least once each week.

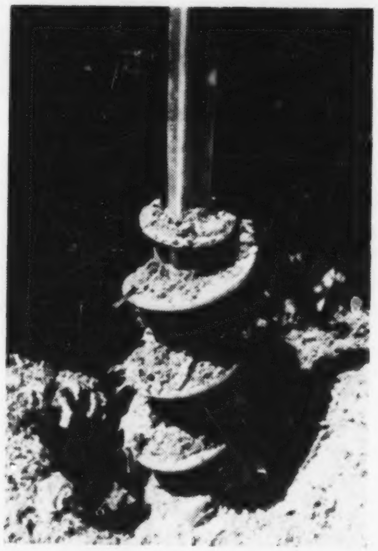
1. Leachates. During the period from February 1972 through November 1972, cumulative rainfall in Oceanside was 4.2 inches onto each cell. Total rainfall onto each cell calculated from surface areas was: Cells 1 and 3 - 18,090 gallons; Cell 2 - 16,690 gallons. These quantities are not adjusted for drainage off of the cells (little drainage occurred since most of the cell surface area will not drain). Similarly, there is no correction for evapotranspiration (there is insignificant plant growth on the cells) or evaporation of surface water. Daily and cumulative rainfall onto Cells 1 and 3 are given in Figure VII-5, and onto Cell 2 in Figure VII-6. Cells 1 and 3 have the same surface area and therefore receive equal rainfall. Cell 2 has a smaller surface area and therefore receives less volume of rainfall.

In addition to rainfall, the following quantities of water in the liquid sludge were applied to each cell during filling: Cell 1 - 44,370 gallons; Cell 2 - 36,400 gallons; and Cell 3 - 53,530 gallons.

Total water into each cell (sludge liquid plus rainfall) from February 1972 through November 1972 was: Cell 1 - 62,460 gallons; Cell 2 - 53,090 gallons; and Cell 3 - 71,620 gallons.

The calculated ratio of lb water (sludge plus rainfall) to lb dry weight solid waste and dry sludge solids in each cell through November 1972 were: Cell 1 - 0.45; Cell 2 - 0.51; and Cell 3 - 0.71. All were in the low end of the laboratory-estimated saturation range of 0.6 to 1.8 lb per lb for the solid waste, dry weight.

a. DRILL RIG.



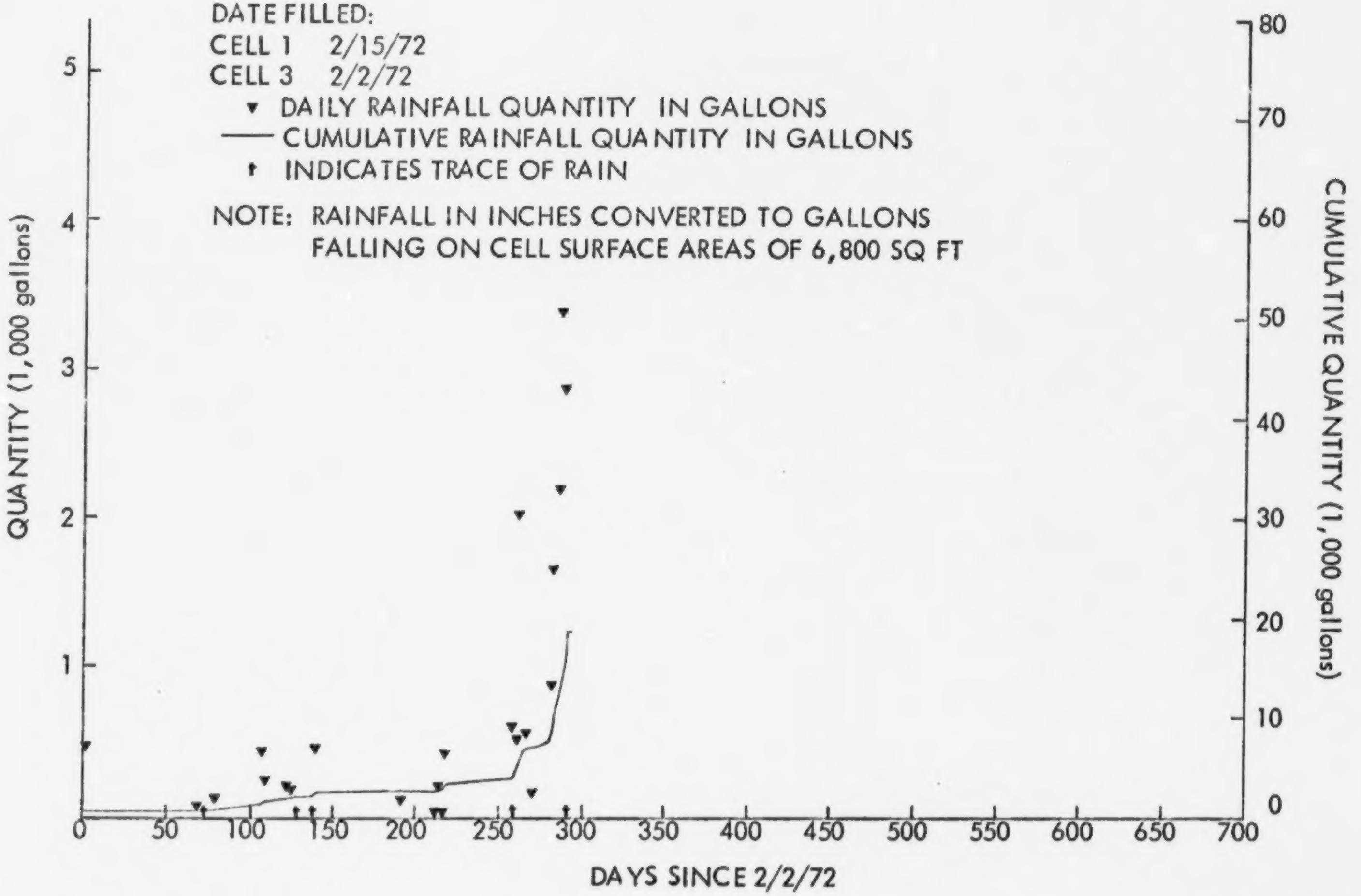
b. AUGER BIT - 12 INCH DIAMETER.

c. MEASURING TEMPERATURE AND SAMPLING CORED MATERIAL.

CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VII-7

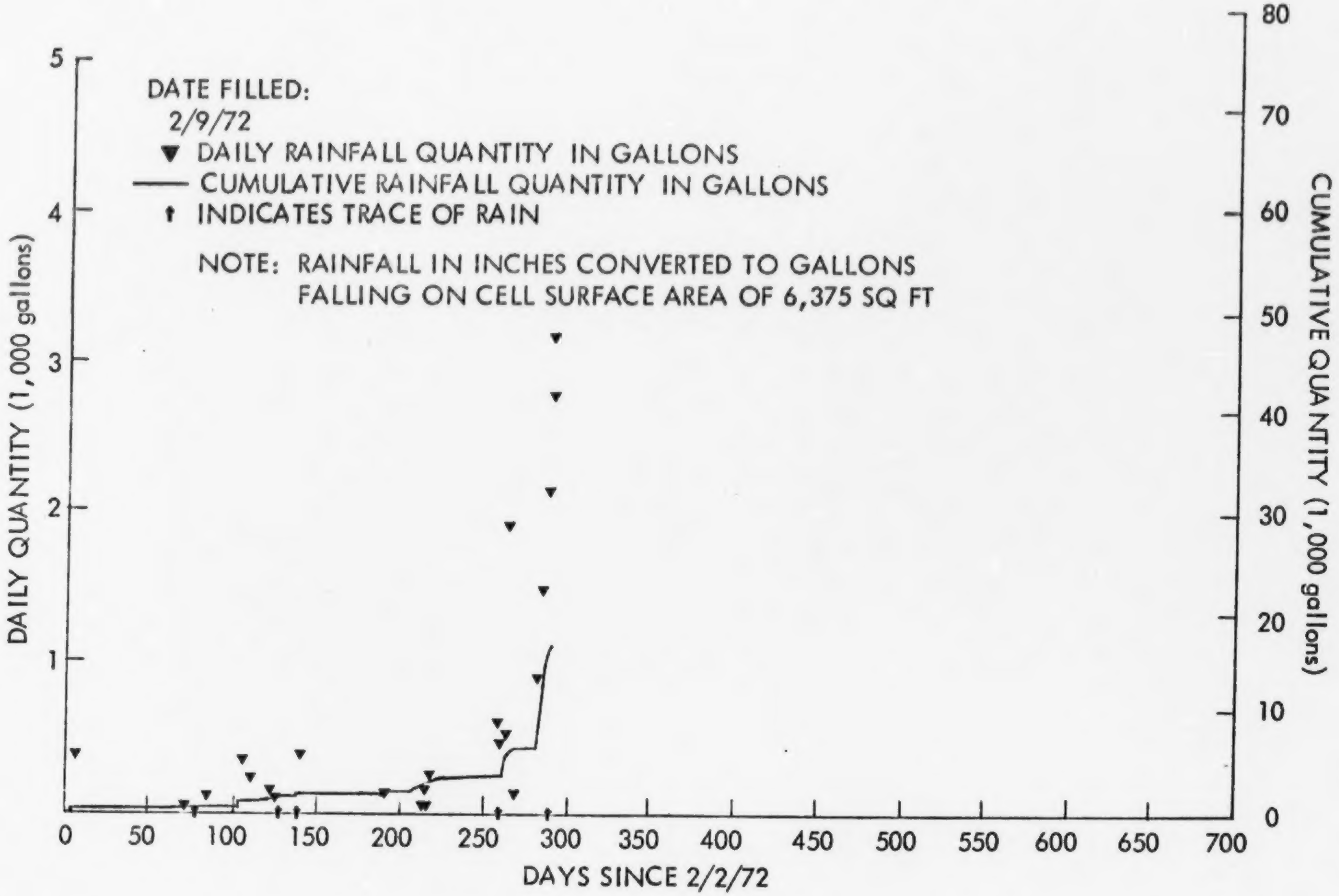
CORE DRILLING EQUIPMENT



CITY OF OCEANSIDE/E.P.A.

FIGURE VII-5

TEST CELLS 1 AND 3
DAILY AND CUMULATIVE RAINFALL



CITY OF OCEANSIDE/E.P.A.

FIGURE VII-6
TEST CELL 2
DAILY AND CUMULATIVE RAINFALL

The daily and cumulative quantities of leachate obtained from Cells 1 and 3 are given in Figures VII-7 and VII-8, respectively. No leachate was obtained from Cell 2. Leachate has been obtained from Cell 1 since the cell was filled, although only in trace amounts (less than 10 ml) since 80 days after filling. The raw primary sludge applied to Cell 1 had relatively non-viscous, fast settling solids (non-homogenous). This permits the liquid to separate from the solid fraction and percolate through the solid waste. The observation that the test cell with the raw primary sludge tended to produce more leachate than the cells with admixed secondary digested sludges is in agreement with the results of pilot drum tests (see Chapter VI). The total quantity of leachate obtained from Cell 1 through November 30 was 44.8 gallons, which is negligible when compared with the 45,500 gallons of raw primary sludge put into Cell 1.

The first leachate was obtained from Cell 3 after 2.63 inches of rainfall during the period November 8 through 18, 1972. A total of 1,403 gallons of leachate were obtained from Cell 3 through November 29, 1973. Since no change in leachate production was observed during the same period in Cells 1 or 2, a short-circuit in Cell 3 was suspected. It was observed that the surface of Cell 3 had settled to form a shallow bowl. An eight-inch deep, two-by-two-foot depression was found near the Cell 3 gas and temperature probes through which the storm drainage short-circuiting was thought to have occurred. The depression was subsequently filled with compacted soil and this eliminated the short-circuiting.

The analyses of the weekly/monthly leachate samples from Cell 1 are given in Figures VII-9 through VII-16. Except for the sample collected on day 43, all leachate samples were fairly similar in physical and chemical characteristics. The day 43 sample had a straw color, and had higher TDS and conductivity, and a lower turbidity content. No explanation is available for the atypical characteristics of this sample.

The data in Figure VII-9 indicates an acidic pH for all leachate samples. The acidic pH may be attributed to the anaerobic decomposition of the sludge and solid waste organic acids. The data also indicate that after the third sample a small but noticeable rise in pH occurred. Figure VII-19 indicates initial BOD_5 levels of 5,000-6,000 mg/l. After the second sample, however, the BOD_5 rose to a level of 19,600 mg/l. A relatively low level of initial BOD_5 and a subsequent rise in BOD_5 has also been observed in the pilot drum tests (see Chapter VI). The initial low BOD_5 levels may correspond to an "acclimation" period during which the proper biological community becomes established. After the biological organism acclimates (the growth/"lag" phase), the degradation of organics proceeds at a faster rate and, hence, more nutrients and microorganisms enter into solution in the leachate, producing a rise in the leachate BOD_5 levels.

Organic Kjeldahl nitrogen levels given in Figure VII-11 show an initial level trend followed by a rise corresponding to the BOD_5 increase. Chlorides (Figure VII-12) have remained fairly constant between 1160 and 1630 mg/l with a slightly increasing trend with time. Analyses vary for turbidity, total dissolved salts, and conductivity (Figures VII-13 to VII-16); they show no consistent trends. Analyses for coliform

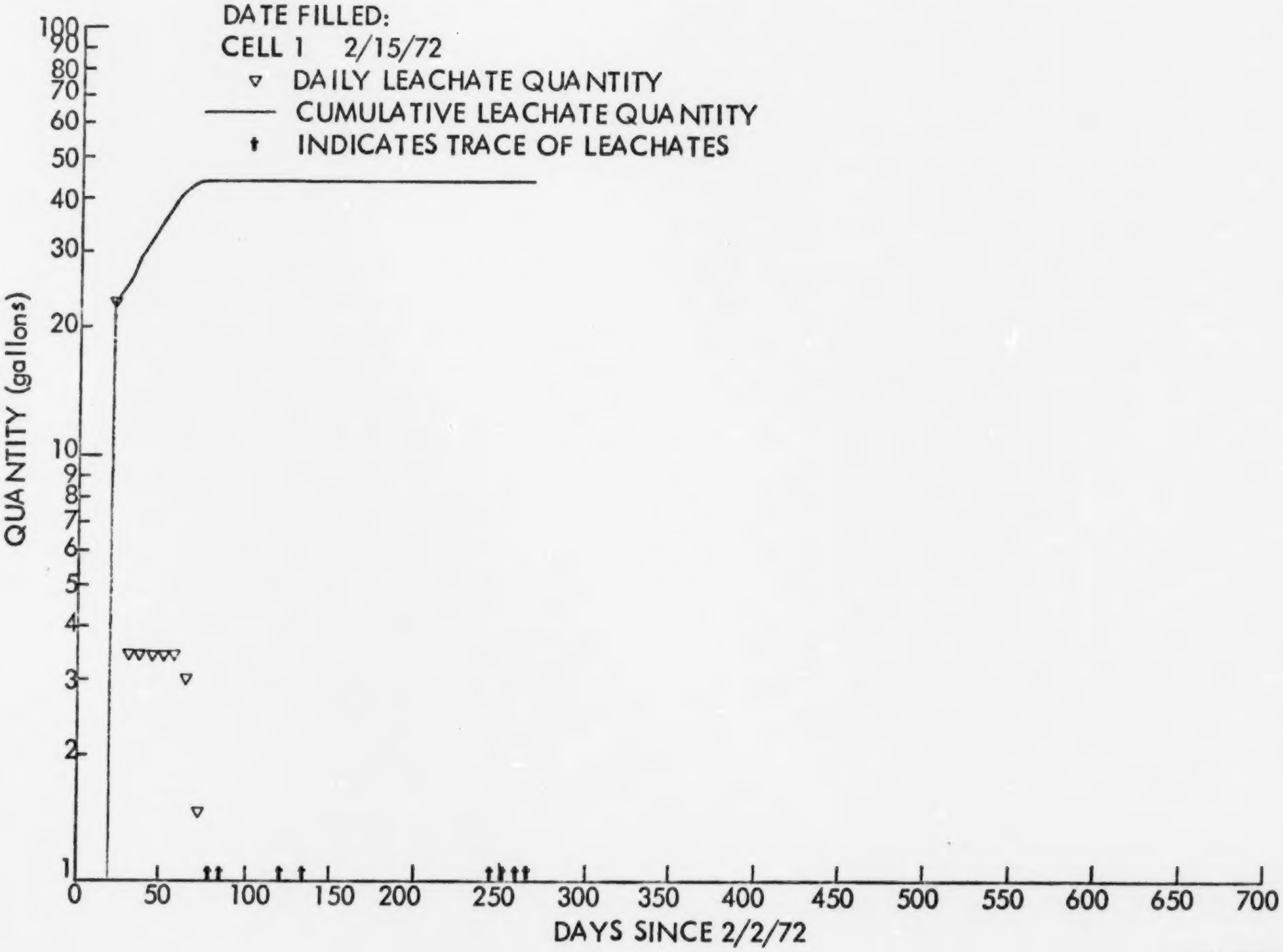


FIGURE VII-7
TEST CELL 1
DAILY AND CUMULATIVE
LEACHATE QUANTITIES

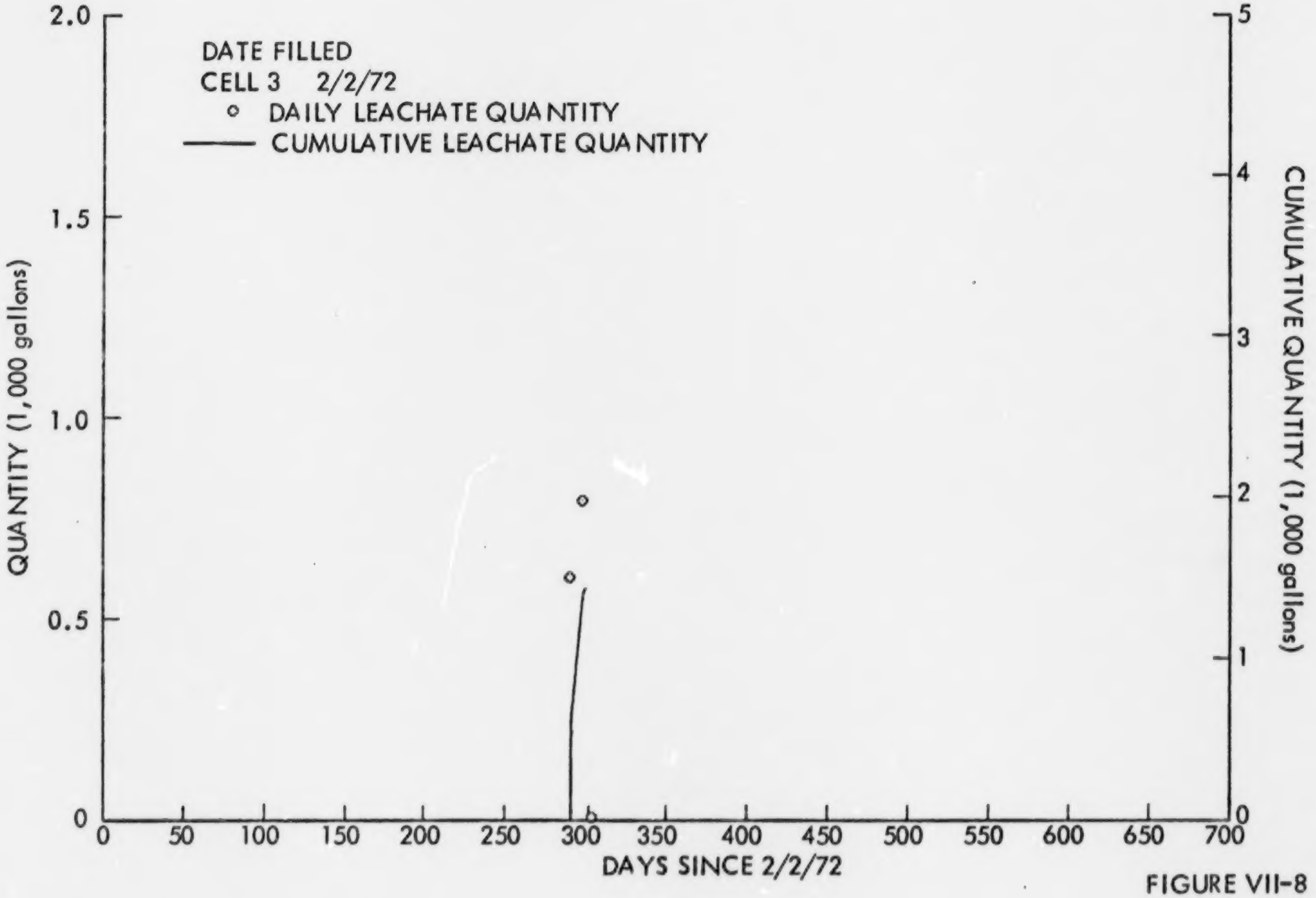
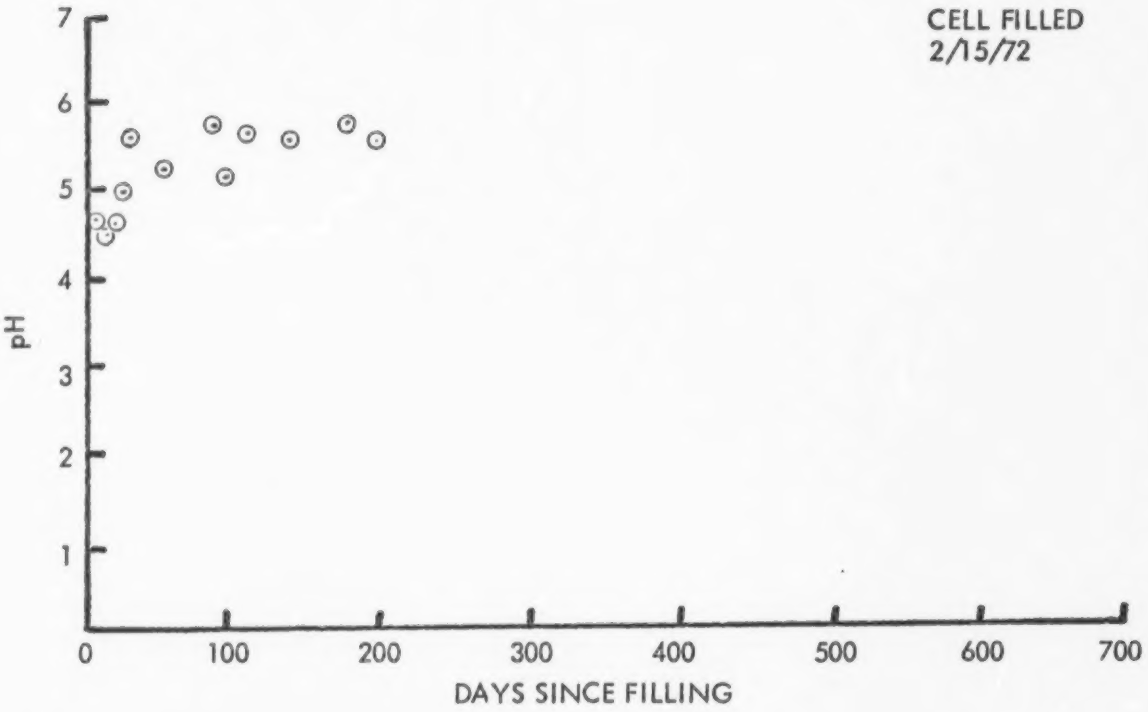


FIGURE VII-8
TEST CELL 3

DAILY AND CUMULATIVE
LEACHATE QUANTITIES

CITY OF OCEANSIDE/E.P.A.



CELL FILLED
2/15/72

CITY OF OCEANSIDE/E.P.A.

FIGURE VII-9

pH OF
TEST CELL 1 LEACHATE

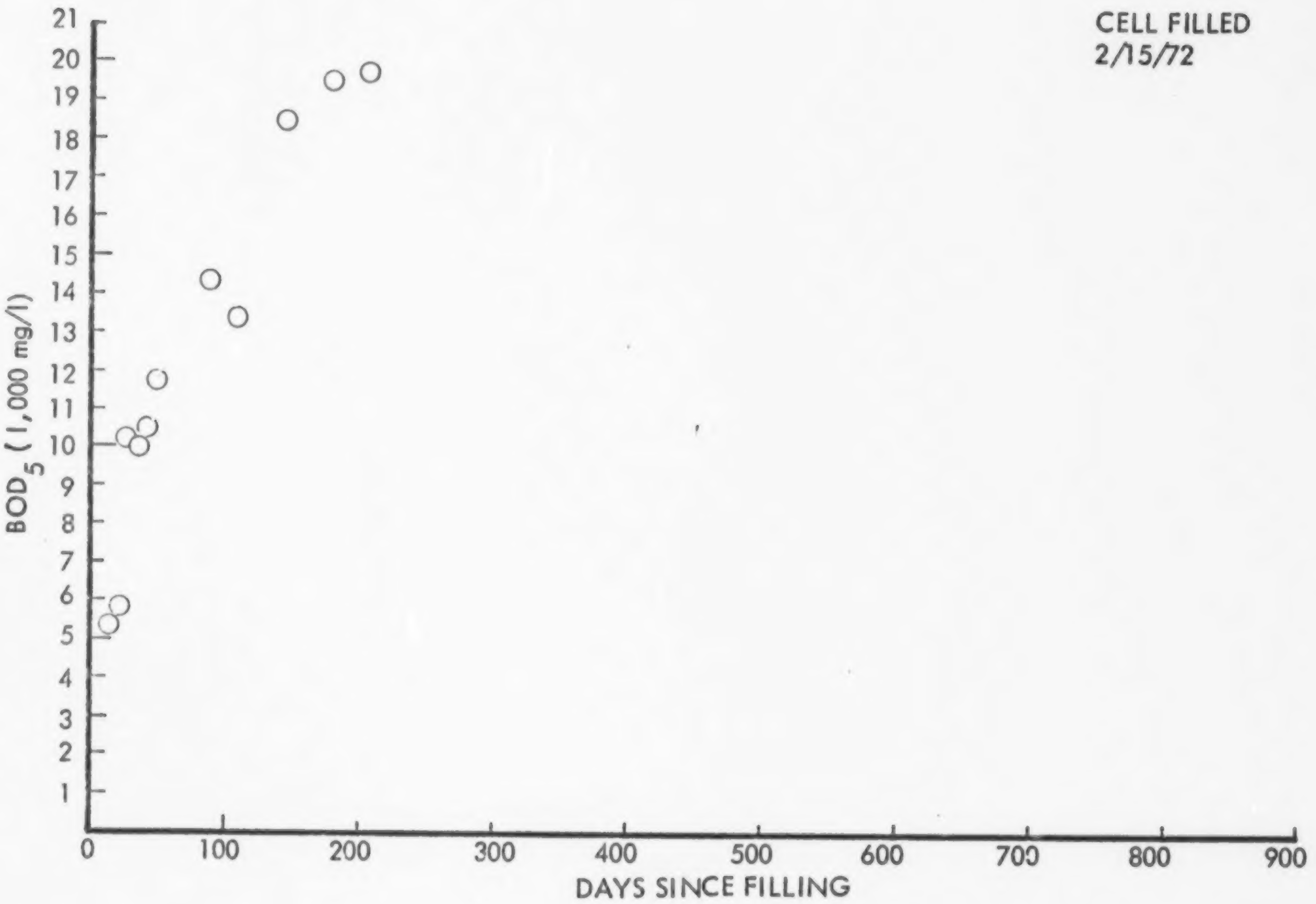
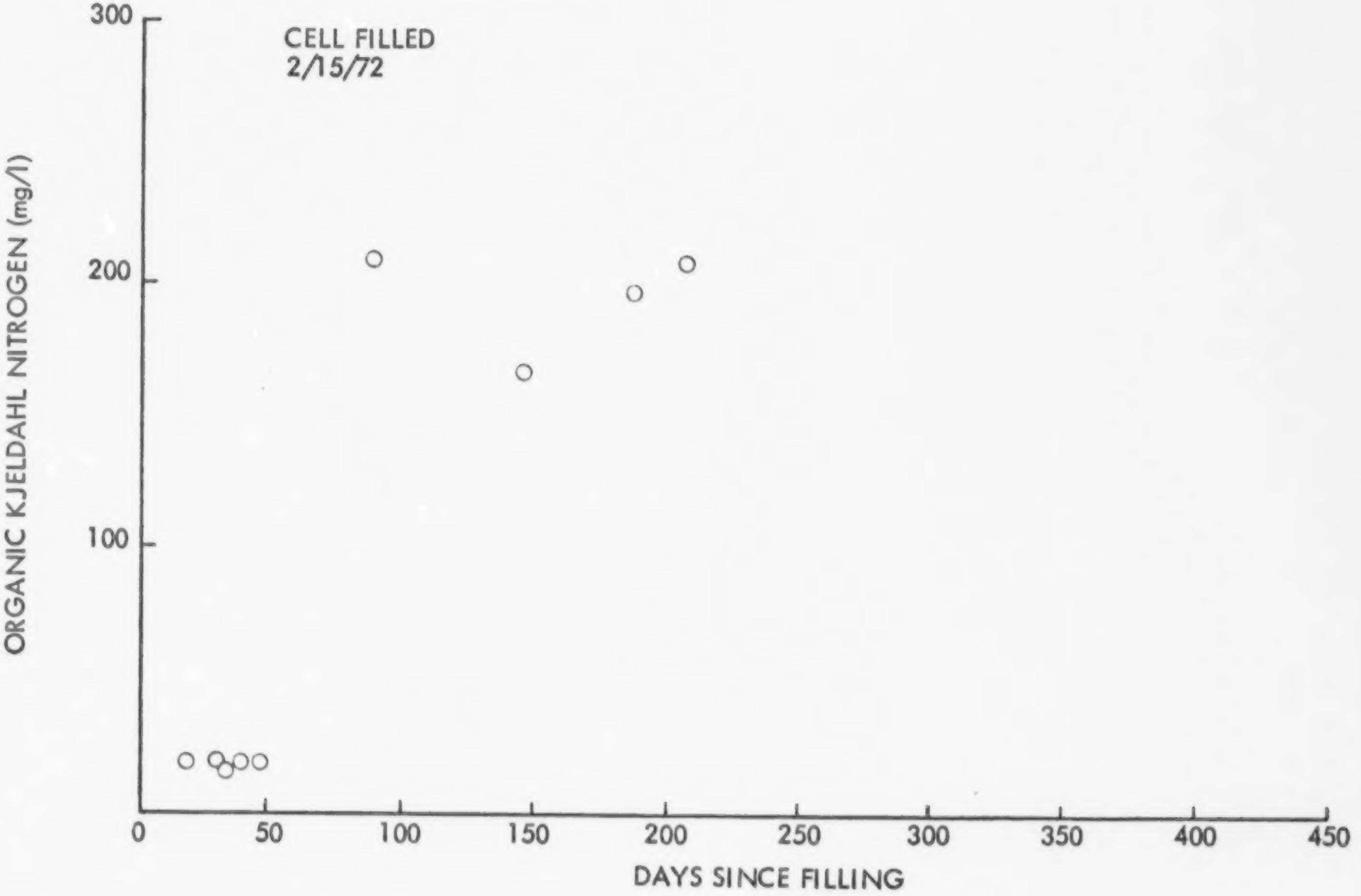


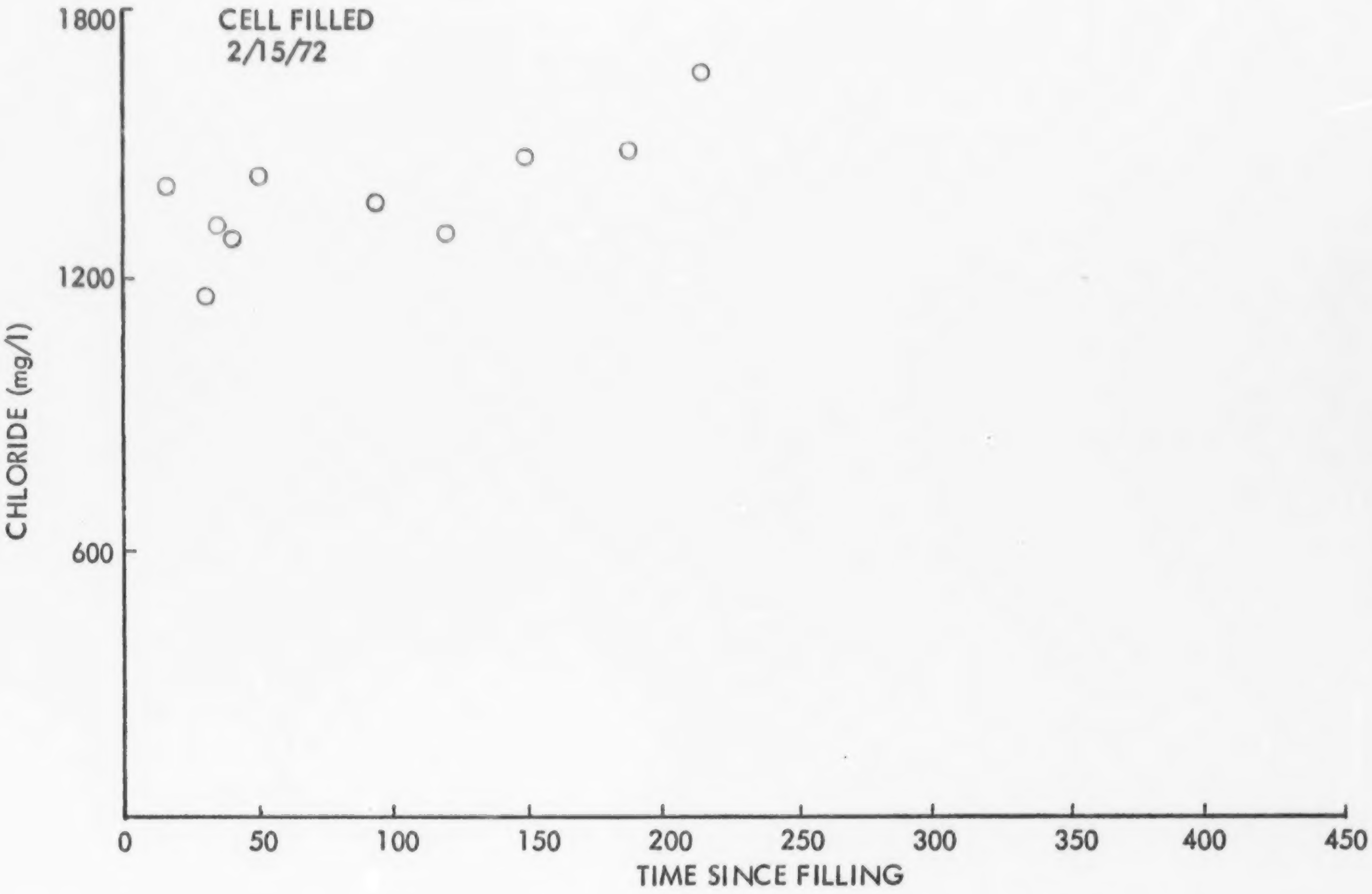
FIGURE VII-10

BOD_5 OF
TEST CELL 1 LEACHATE



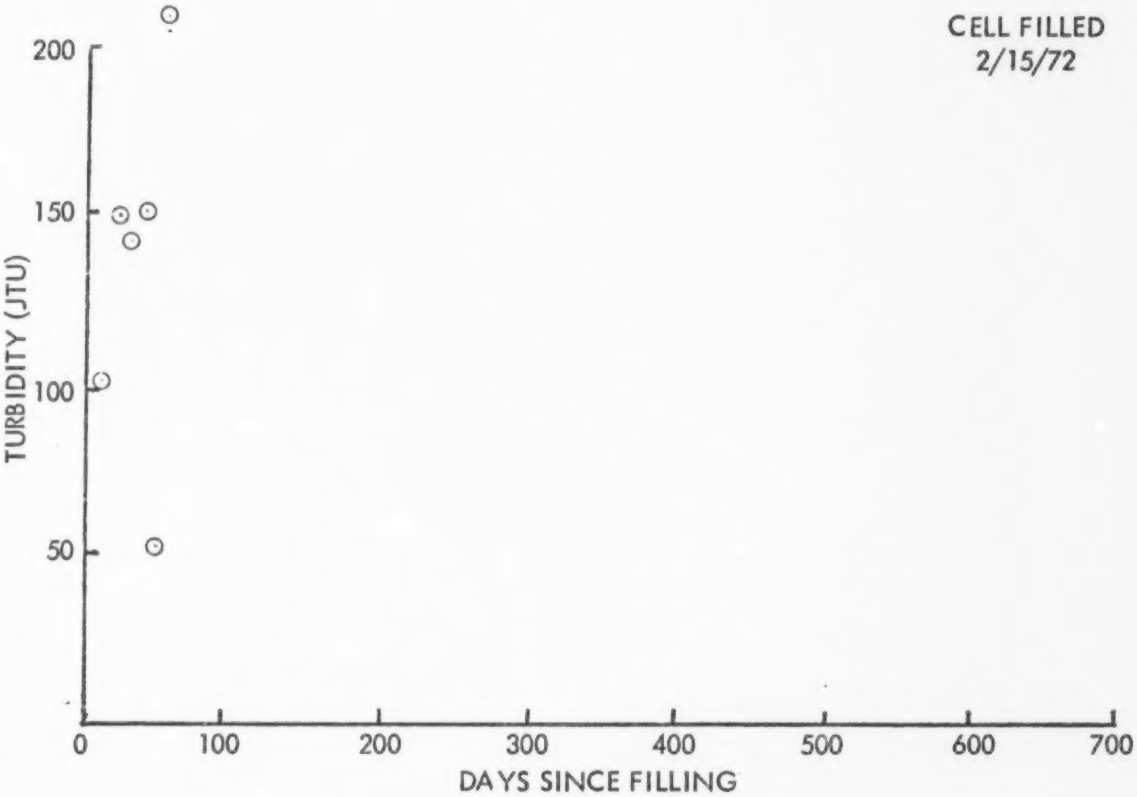
CITY OF OCEANSIDE/E.P.A.

FIGURE VII-11
ORGANIC KJELDAHL NITROGEN
OF TEST CELL 1 LEACHATE



CITY OF OCEANSIDE/E.P.A.
RALPH STONE AND COMPANY, INC.

FIGURE VII-12
CHLORIDE OF
TEST CELL 1 LEACHATE

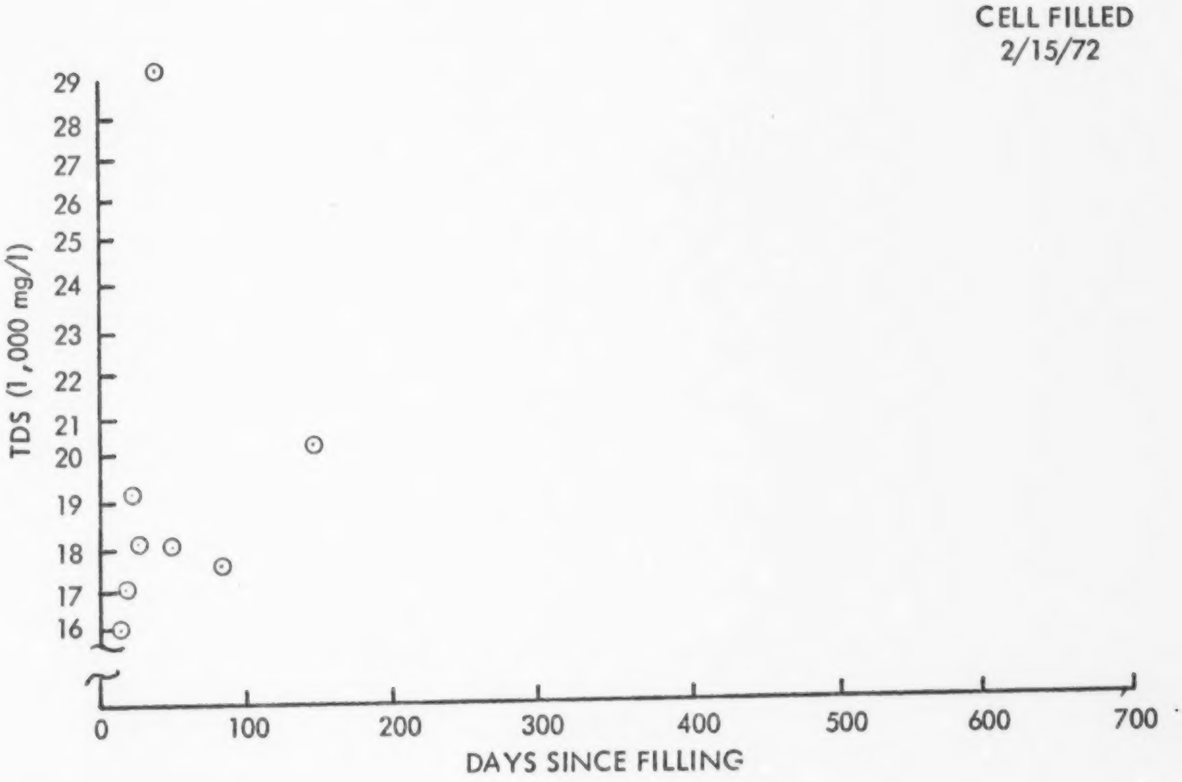


CELL FILLED
2/15/72

FIGURE VII-13

TURBIDITY OF
TEST CELL 1 LEACHATE

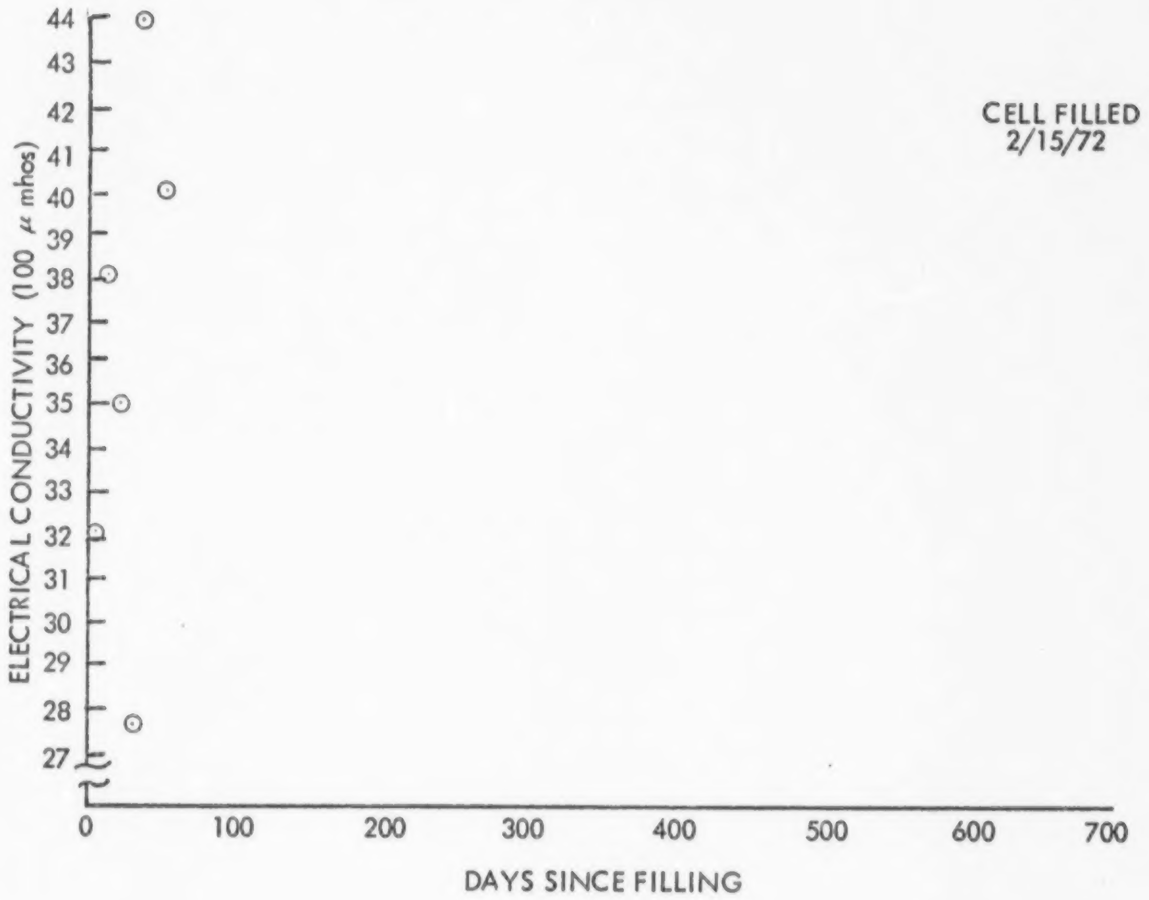
CITY OF OCEANSIDE/E.P.A.



CITY OF OCEANSIDE/E.P.A.

FIGURE VII-14

TOTAL DISSOLVED SALTS OF TEST CELL 1 LEACHATE

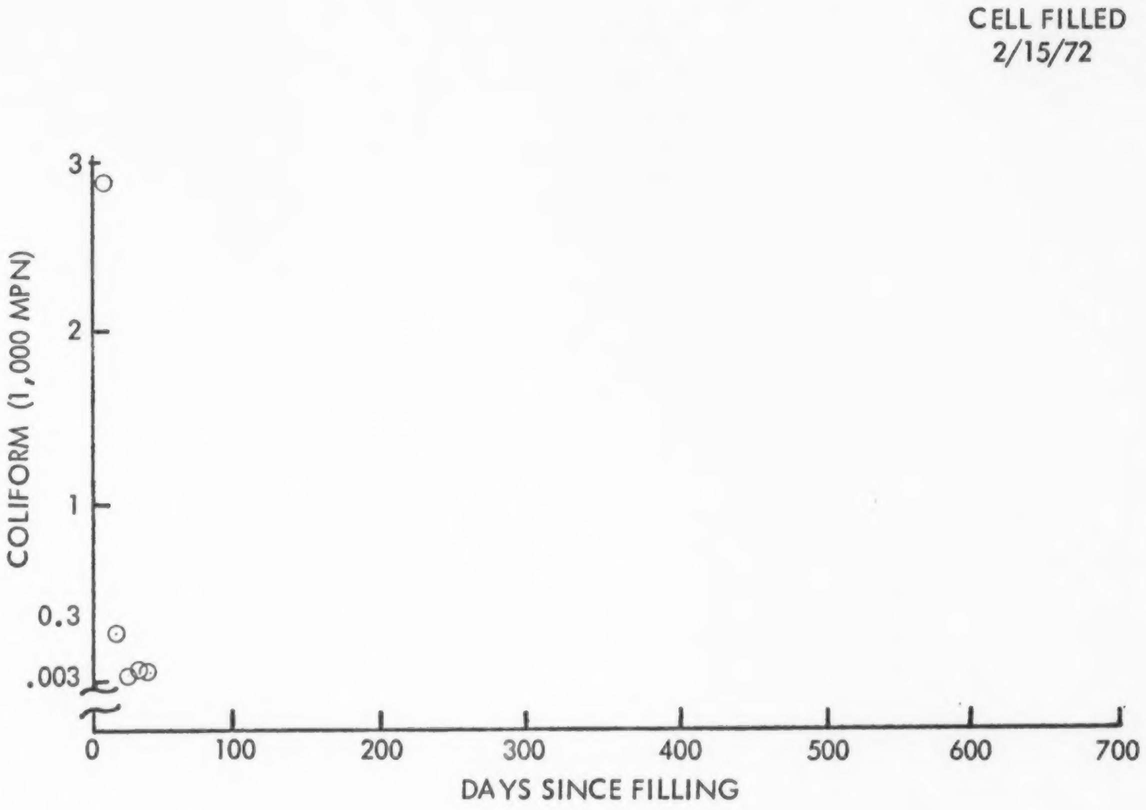


CELL FILLED
2/15/72

CITY OF OCEANSIDE/E.P.A.

FIGURE VII-15

CONDUCTIVITY OF
TEST CELL 1 LEACHATE



CITY OF OCEANSIDE/E.P.A.

FIGURE VII-16

COLIFORM
TEST CELL 1 LEACHATE

(Figure VII-16) showed an initial MPN greater than 3,000, with subsequent MPN less than 0.3.

Table VII-7 presents the comprehensive analysis for a quarterly composite leachate sample from Cell 1. Of particular interest is the very low concentration of heavy metals (chromium, copper, and lead) in the leachate. These elements were at such low concentrations that they could not be detected by the analytical techniques used. The pesticide aldrin was found to be present in the leachate at a level of 0.015 mg/l. The presence of pesticide in the leachate is not surprising since many pesticides are fairly resistant toward biological oxidation and would be expected to survive the anaerobic landfill environment.

Analyses of leachate samples from Cell 3 are given in Table VII-8. These analyses show the leachate to be acidic, as in Cell 1. Of note are the chlorides and turbidity which were significantly less than the values obtained for the Cell 1 leachate. This would result from the rain water short circuiting and dilution of leachate from Cell 3. The more soluble ionic components of the sludge/solid waste fill were easily leached by the rainwater as evidenced by the higher conductivity in Cell 3 leachate over Cell 1. The BOD_5 for Cell 3 was an order of magnitude lower than for Cell 1, which was attributed to the dilution resulting from the short-circuit path through Cell 3.

2. Temperature. A summary of temperature data collected at three different depths within each cell is given in Table VII-9. The temperature trends are plotted in Figures VII-17 to VII-19.

The average temperatures and maximum variations from average in each test cell since filling through November 28, 1972 were as follows:

Depth, ft.	Temperature, deg. F Cell 1		Cell 2		Cell 3	
	Avg	Max var	Avg	Max var	Avg	Max var
7-8	84	+6	81	-11	84	-14
8-10.5	78	±4	80	-5	83	-23
15-17.8	70	-5	70	-6	72	+20

The temperature variations in Cell 1 and 2 were small and tended to follow ambient temperatures at the 7 to 8-foot depth. Variations in Cell 3 temperature were large, with the greatest variances (shown above and in Figure VII-19) occurring in November 1972 (day 250 plus) when 2.63 inches of rainfall short-circuited through Cell 3 in the vicinity of the temperature probes.

TABLE VII-7
CELL 1 COMPREHENSIVE QUARTERLY LEACHATE ANALYSES*

Constituent	Concentration (mg/l)	Constituent	Concentration (mg/l)
Cations:		Metals:	
Calcium	1,380	Boron	17
Magnesium	425	Iron	4.7
Sodium	1,320	Manganese	0
Potassium	700	Hexavalent chromium	<0.05
		Arsenic	0
Anions:		Lead	<0.05
Hydroxide	0	Copper	<0.05
Carbonate	0		
Bicarbonate	6,771	Others:	
Sulfate	1,047	Phenols	0.01
Chloride	1,600	Silica	93
Nitrate, NO_3	3.2	Ortho phosphate	0.37
		Nitrate, N	0.71
Oxygen consumed	25,000	Total alkalinity ($Ca CO_3$)	5,550
Herbicide	None	Total hardness ($CaCO_3$)	5,200
Pesticide - aldrin	0.015	Dissolved solids	17,956
pH	6.1	Conductivity (μmhos/cm)	18,000

*Composite sample taken April 6, 1972. Analyses performed by Environmental Engineering Laboratory, San Diego, California at the request of the City of Oceanside. Metals analyses were done by atomic absorption spectrophotometry.

TABLE VII-8
CELL 3 LEACHATE ANALYSIS

Analysis	Days since filling *	
	296	301
Color	Dark grey	Yellow, partially translucent when sampled; turned dark grey, opaque, after 4 hours.
pH	5.12	5.35
Conductivity (μ-mhos	4,000	6,500
Turbidity (JTU)	42	74
BOD_5 (mg/l)	1,050	1,400
Chlorides (mg/l)	595	740
Organic Kjehdahl nitrogen (mg/l)	107	70.3

* Cell 3 completed filling February 2, 1972.

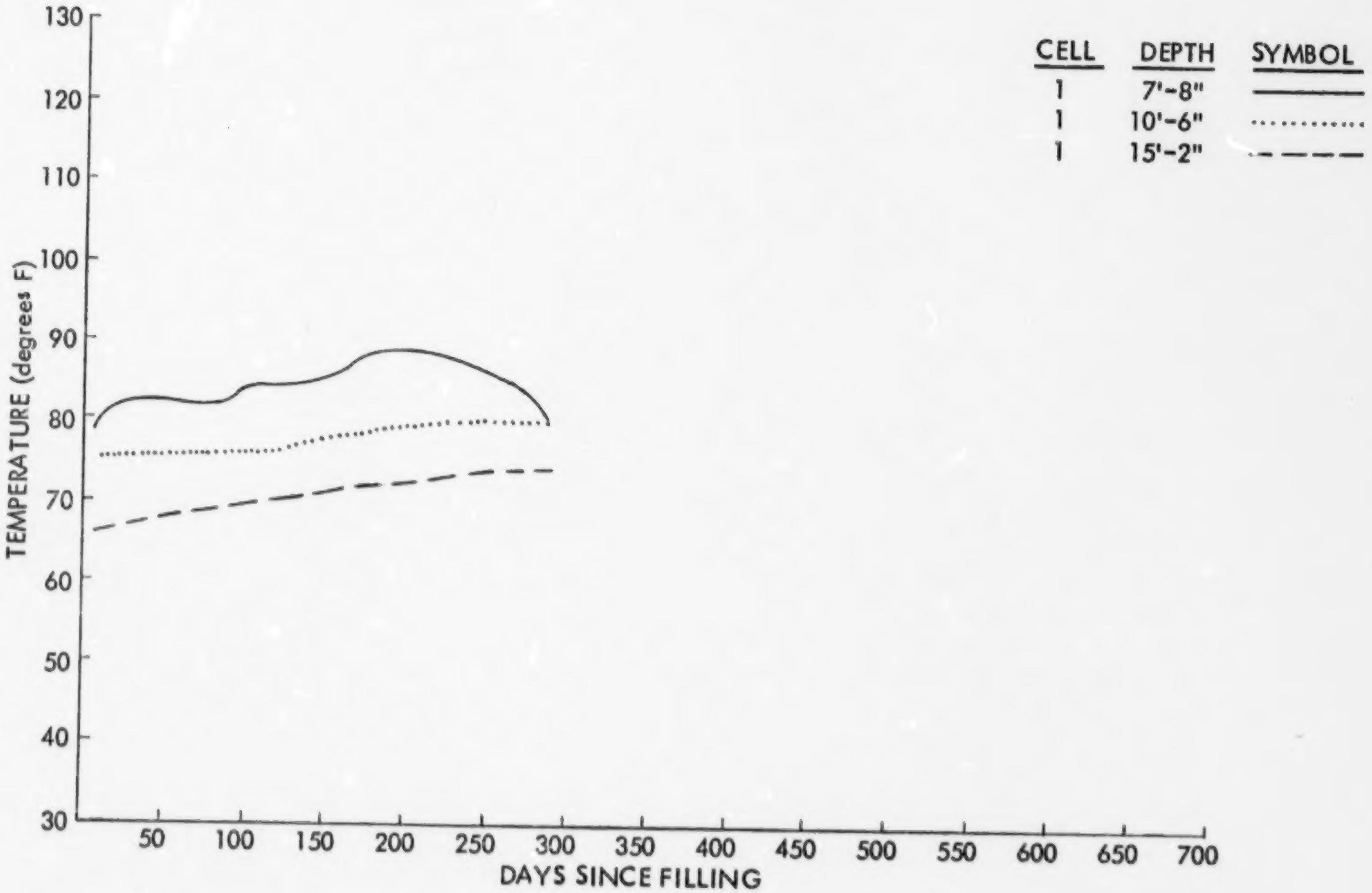
TABLE VII-9
OCEANSIDE TEST CELL TEMPERATURE RECORD

	Temperature, degrees F by day since filling												
			Cell 1 - depth				Cell 2 - depth				Cell 3 - depth		
Date	Ambient max/min	Days since filling	7'-8"	10'-6"	15'-2"	Days since filling	7'-0"	9'-5"	17'-9"	Days since filling	6'-0"	8'-4"	15'-5"
1972													
2/23	64/50	8	79	74	66	14	70	75	64	21	78	80	66
2/24	59/45	9	80	76	68	15	78	77	-	22	81	84	66
2/25	60/41	10	80	74	65	16	70	77	-	23	80	84	66
2/28	58/47	13	82	76	65	19	72	76	64	26	80	80	-
2/29	65/51	14	82	76	66	20	74	78	68	27	80	84	66
3/7	61/52	21	82	76	67	27	74	78	70	34	79	83	68
3/14	62/54	28	83	76	66	34	74	78	66	41	80	82	67
3/21	68/55	35	84	78	68	41	76	78	72	48	79	82	68
3/30	67/42	44	82	78	68	50	78	78	69	57	81	82	69
4/4	70/53	49	82	76	68	55	78	78	70	62	80	84	69
4/11	68/49	56	83	76	68	62	80	78	70	69	86	84	68
4/18	63/52	63	82	76	68	69	78	78	70	76	82	84	70
4/25	68/51	70	82	76	68	76	78	78	70	83	82	82	70
5/2	71/54	77	82	76	69	83	80	78	72	90	82	82	70
5/9	71/52	84	82	76	68	90	80	78	72	97	82	82	70
5/16	71/58	91	82	76	69	97	80	78	68	104	84	82	72
5/23	71/52	98	83	76	70	104	80	78	68	111	84	83	71
5/30	76/60	105	84	76	70	111	82	80	69	118	86	84	72
6/6	73/63	112	84	76	70	118	82	80	69	125	86	84	72
6/13	74/61	119	84	76	70	125	82	NR *	70	132	86	80	72
6/20	75/62	126	84	76	70	132	82	80	70	139	86	84	72
6/27	74/56	133	84	76	70	139	82	NR *	70	146	88	86	74
7/5	75/56	141	85	78	70	147	84	80	70	154	88	86	74
7/11	77/61	147	84	78	70	153	84	80	70	160	88	86	74
7/18	80/67	154	86	78	72	160	85	80	70	167	90	88	74

TABLE VII-9
OCEANSIDE TEST CELL TEMPERATURE RECORD

	Temperature, degrees F by day since filling												
		Days since	Cell 1 - depth			Days since	Cell 2 - depth			Days since	Cell 3 - depth		
Date	Ambient max/min	filling	7'-8"	10'-6"	15'-2"	filling	7'-0"	9'-5"	17'-9"	filling	6'-0"	8'-4"	15'-5"
7/25	80/68	161	86	78	72	167	86	80	70	174	90	88	74
8/1	86/65	168	86	78	72	174	86	82	70	181	92	88	76
8/8	79/66	175	88	80	72	181	88	82	72	188	94	90	76
8/15	80/64	182	88	78	72	188	88	82	72	195	96	90	76
8/22	87/62	189	88	78	72	195	88	82	72	202	92	90	78
8/29	78/65	196	88	78	72	202	88	82	72	209	90	90	76
9/5	82/64	203	88	78	72	209	88	82	72	216	94	90	74
9/12	76/55	210	84	80	74	216	83	83	73	223	94	88	74
9/19	76/57	217	88	80	72	223	83	82	73	230	94	90	74
9/26	76/54	224	86	80	72	230	84	82	72	237	92	88	74
10/3	77/53	231	84	80	74	237	84	82	74	244	92	74	78
10/10	75/57	238	90	82	72	244	84	84	72	251	86	90	92
10/17	70/55	245	88	80	72	251	84	82	72	258	90	86	79
10/24	82/54	252	86	80	74	258	82	80	72	265	78	76	74
10/31	69/47	259	86	80	74	265	82	80	72	272	80	80	74
11/7	67/51	266	84	80	74	272	80	82	73	279	80	80	74
11/14	62/47	273	84	80	74	279	78	80	72	286	60	60	70
11/21	72/43	280	82	80	74	286	76	80	72	293	62	62	68
11/28	73/50	287	80	80	74	293	74	78	72	300	64	62	70

* NR = not recorded due to broken thermometer.



CITY OF OCEANSIDE/E.P.A.

FIGURE VII-17
OCEANSIDE TEST
CELL 1 TEMPERATURE

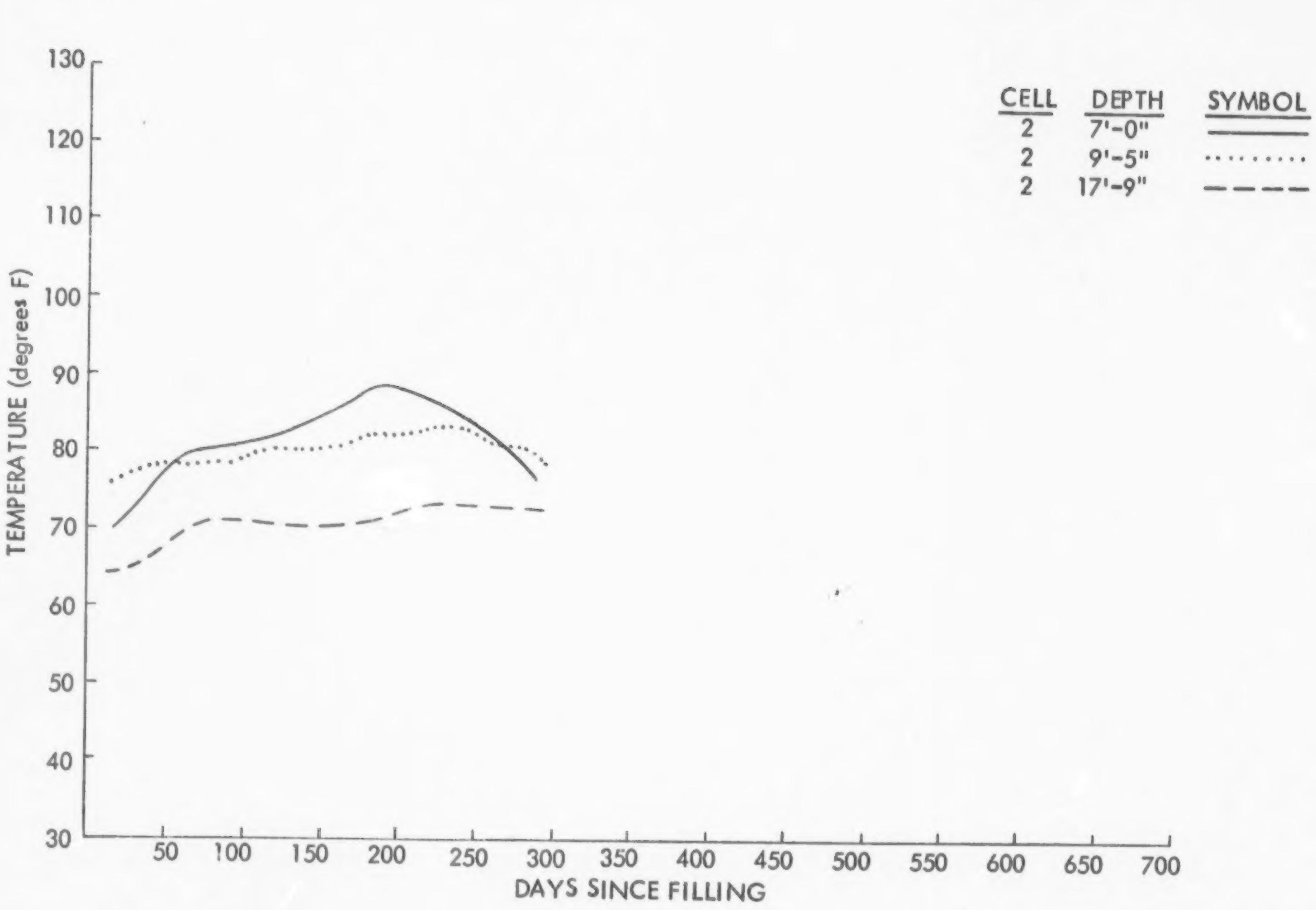
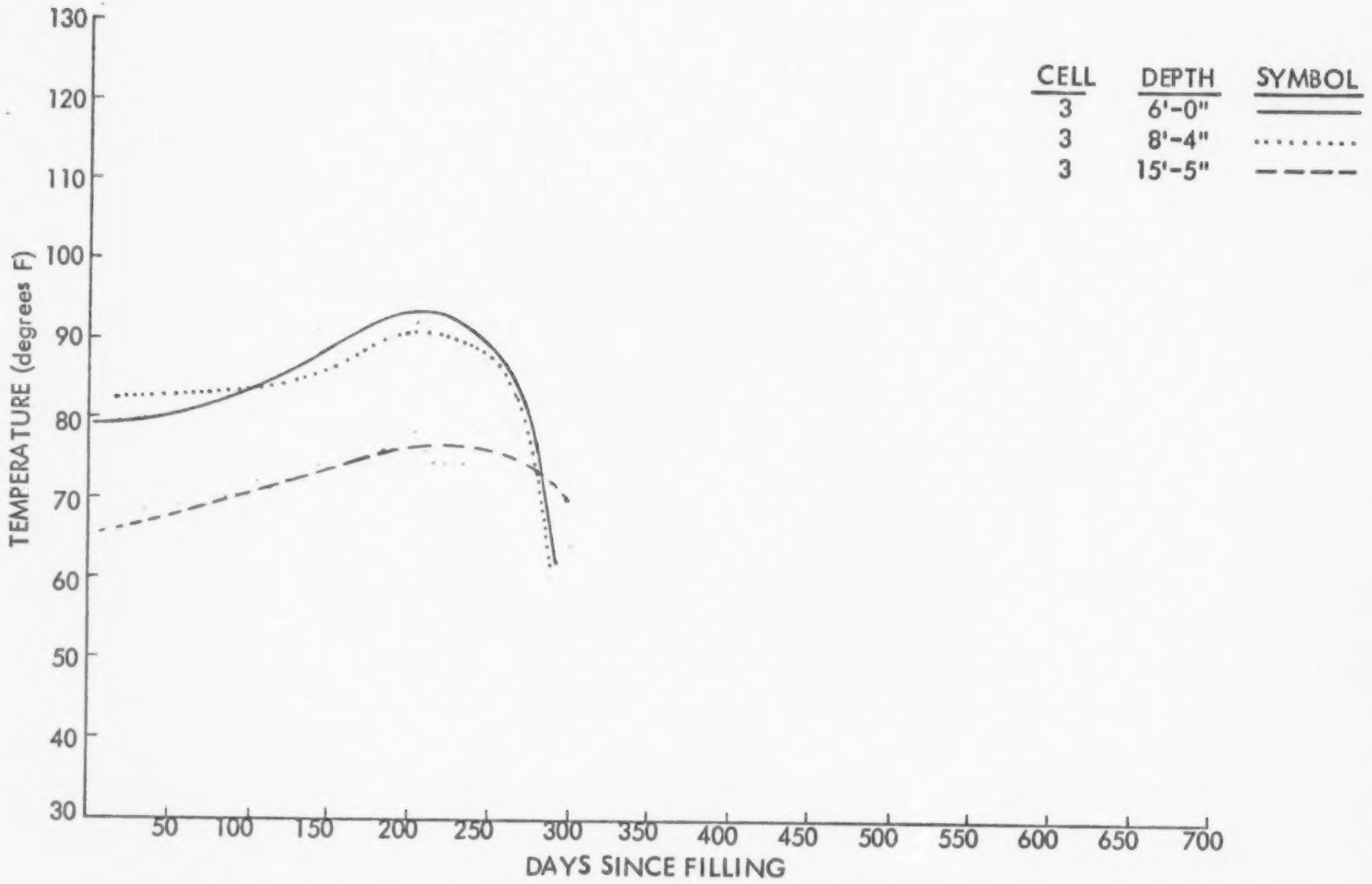


FIGURE VII-18
OCEANSIDE TEST
CELL 2 TEMPERATURE



CITY OF OCEANSIDE/E.P.A.

FIGURE VII-19
OCEANSIDE TEST
CELL 3 TEMPERATURE

3. Gas Analyses. Gas analysis results are presented in Figures VII-20 through VII-25. The methane and carbon dioxide concentrations at mid-depth and bottom probes in Cell 1 show generally increasing trends. Methane data on Cells 2 and 3 show trends similar to Cell 1. Carbon dioxide content in Cell 2 differs from trends in Cells 1 and 3 in that the CO_2 level did not drop to a low of two percent after the initial peak. The low two percent CO_2 readings in Cell 1 and 3 were probably erroneous gas samples. Data collected prior to May 1972 were considered less accurate than subsequent data due to problems in field sampling procedures. These problems were minimized after the end of May 1972 by replacing plastic tape gas probe seals with airtight screw plastic caps and plastic valves to eliminate air contamination.

Reports were received from personnel taking temperature measurements that odors were emitted from the temperature probes when opened. Several tests were made for hydrogen sulfide (H_2S) gas in June and July 1972. Hydrogen sulfide was detected in the following concentrations on days since filling as shown below:

Days since filling	Concentration, mg/l Cell 1 Mid-depth	 Cell 1 Bottom	 Cell 2 Mid-depth	 Cell 2 Bottom	 Cell 3 Mid-depth	 Cell 3 Bottom
135-148	25	750	25	10	5	1
141-154	5	9	5	5	5	8
155-168	10	100	8	8	5	5

The H_2S concentration in Cell 1 is significantly greater than found in Cells 2 and 3, probably as a result of the raw primary sludge admixed in Cell 1. The H_2S odor was not detectable when the gas and temperature probes were sealed. Some fine cracks 1/8 in. by 6 in. were observed in the cell soil cover during June, 1972 but no odors were detected escaping through these cracks.

4. Settlement. Settlement curves are given for the three test cells in Figure VII-26. Settlement occurred at the following rates during the first 300 days: Cell 1 - 1.1 percent; Cell 2 - 1.8 percent; and Cell 3 - 2.7 percent. The cause of the wide variations in settlement between the cells is probably due to the variable compaction during placement and the rainfall infiltration; the in-place initial densities (Table VII-5) do not indicate overall variations in cell densities sufficient to account for the settlement difference.

5. Core Sampling. The results of the test cell core sampling completed on July 26, October 2 and available data from November 29, 1972 are discussed in the following paragraphs. The cell corings were delayed due to unforeseen funding and scheduling factors.

a. Temperature Profiles. The temperature profiles by depth, and ambient air temperatures are given in Tables VII-10 through VII-12 for Cells 1 through 3, respectively. The low ambient air temperature for the first sampling is due to the fact that the drilling was done in the morning; the later two drillings were performed in

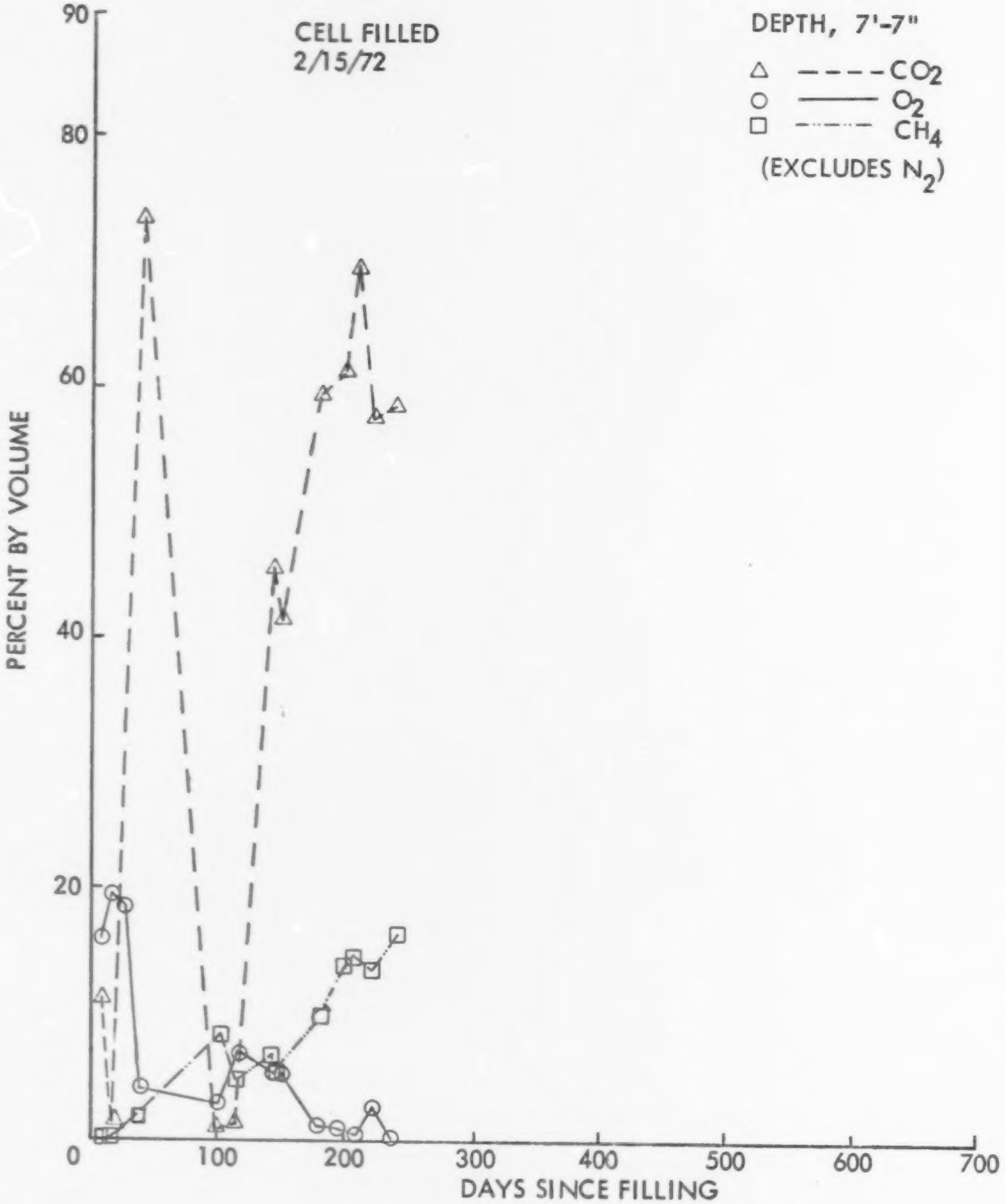


FIGURE VII - 20

GAS ANALYSIS
TEST CELL 1

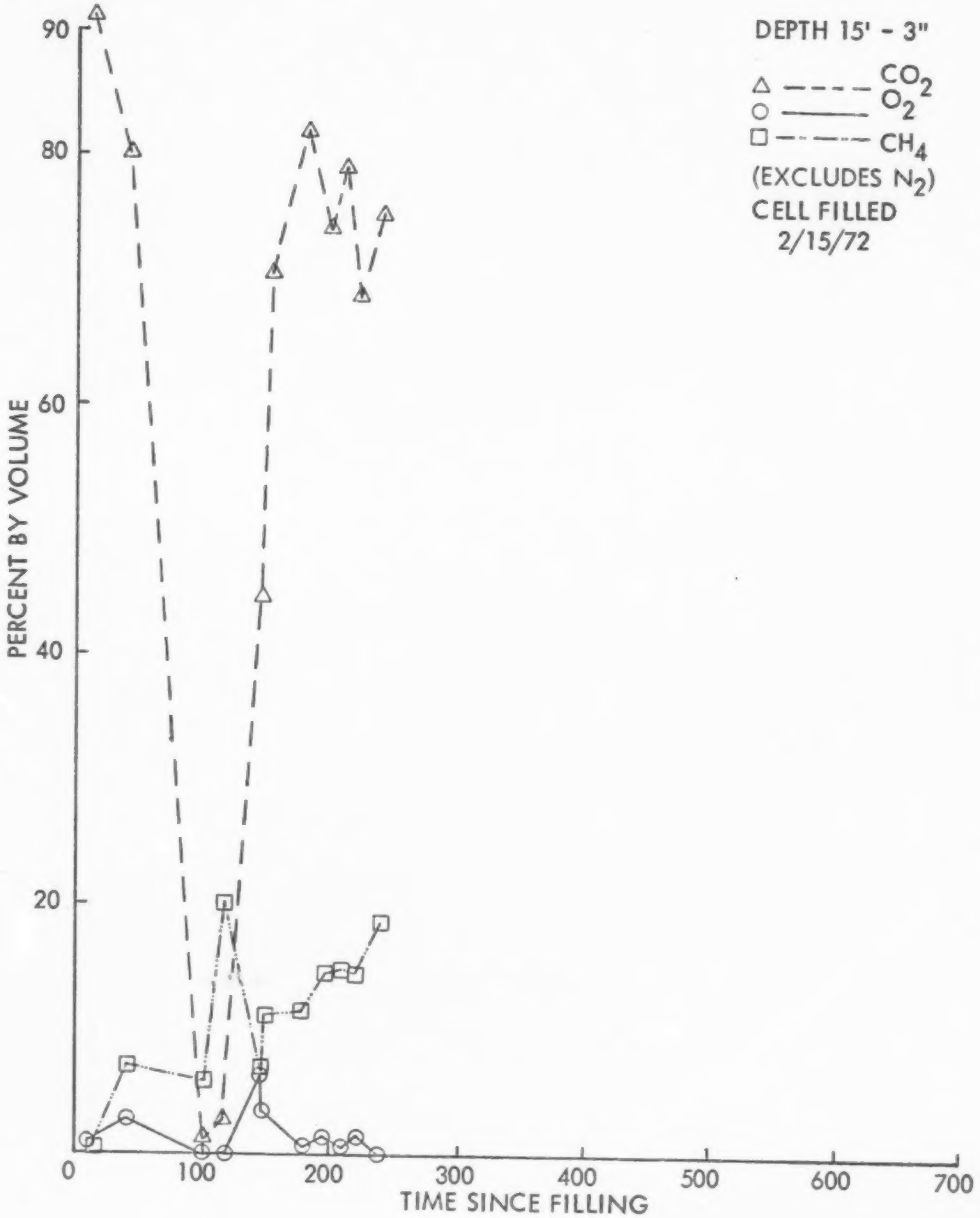


FIGURE VII-21

GAS ANALYSIS
TEST CELL 1

CITY OF OCEANSIDE/E.P.A.

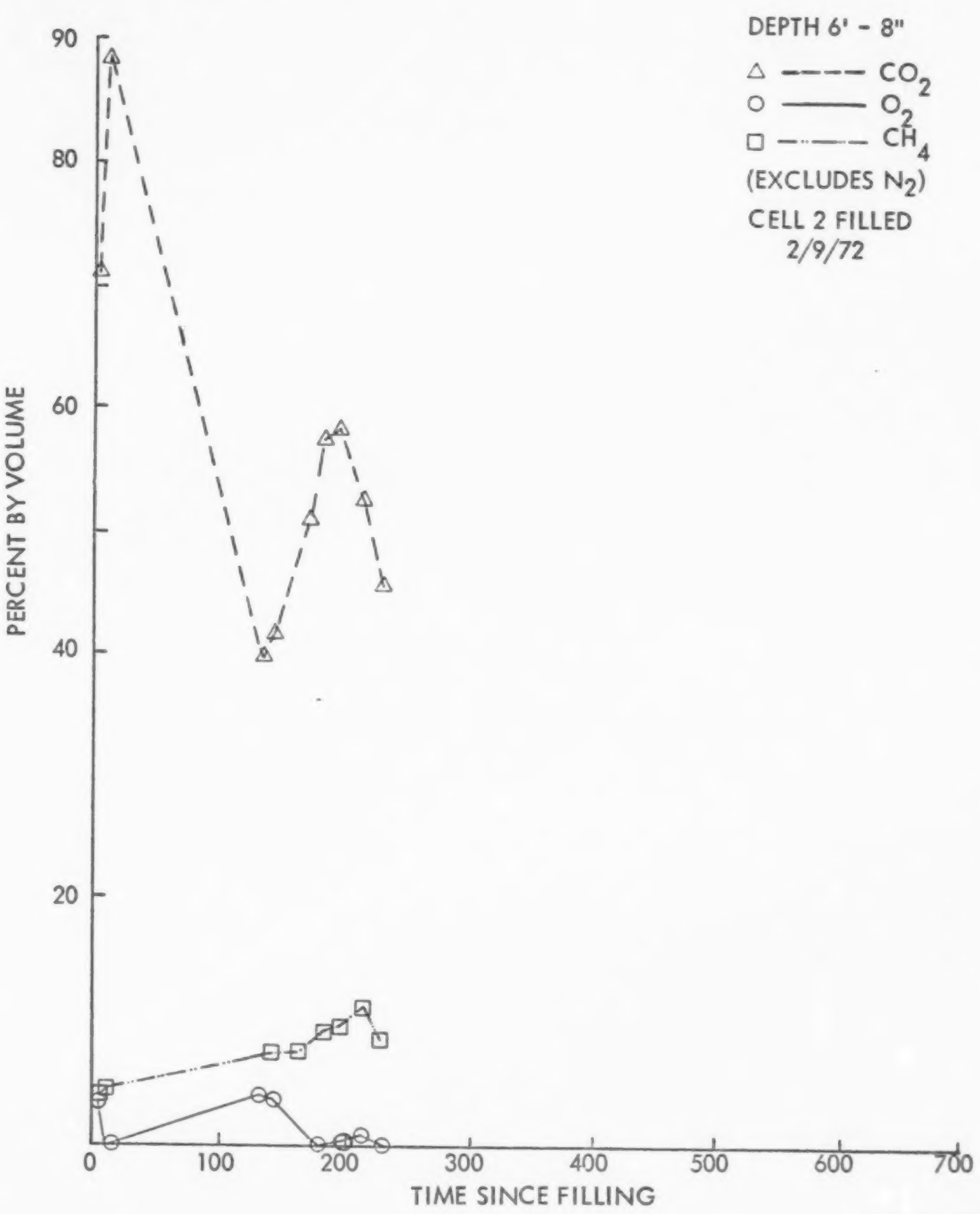


FIGURE VII-22

GAS ANALYSIS
TEST CELL 2

CITY OF OCEANSIDE/E.P.A.

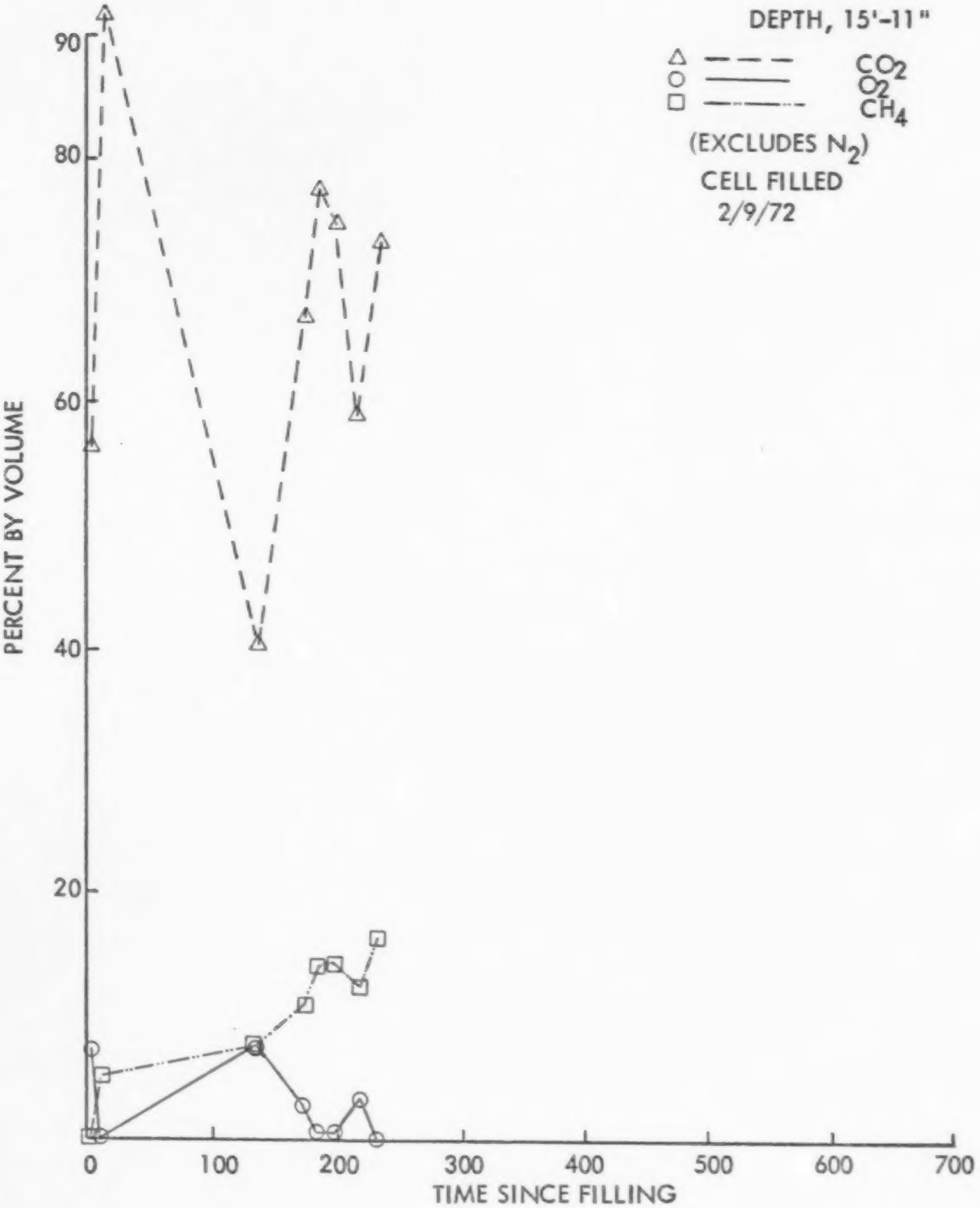
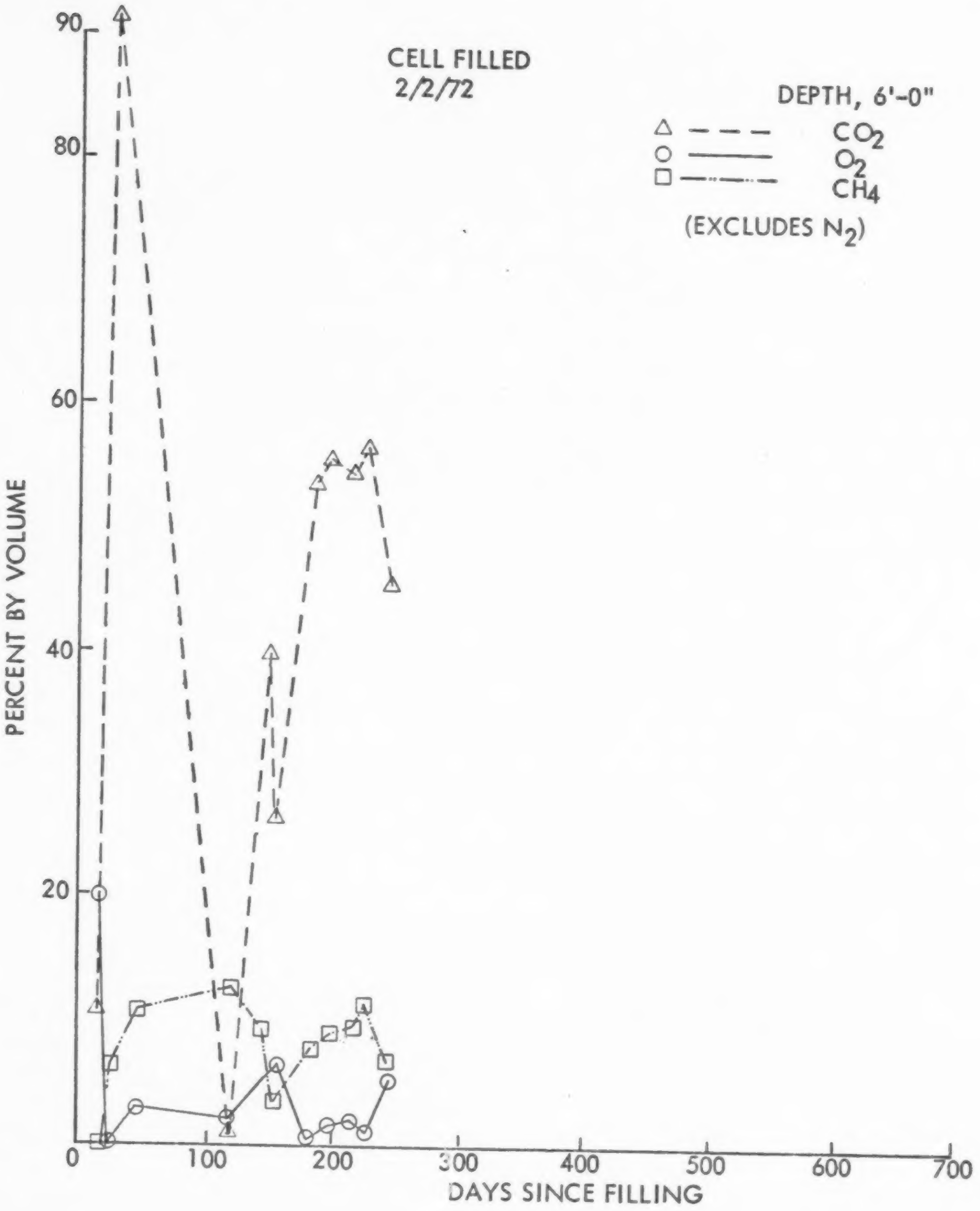


FIGURE VII-23

GAS ANALYSIS
TEST CELL 2

CITY OF OCEANSIDE/E.P.A.



CITY OF OCEANSIDE/E.P.A.

FIGURE VII-24

GAS ANALYSIS
TEST CELL 3

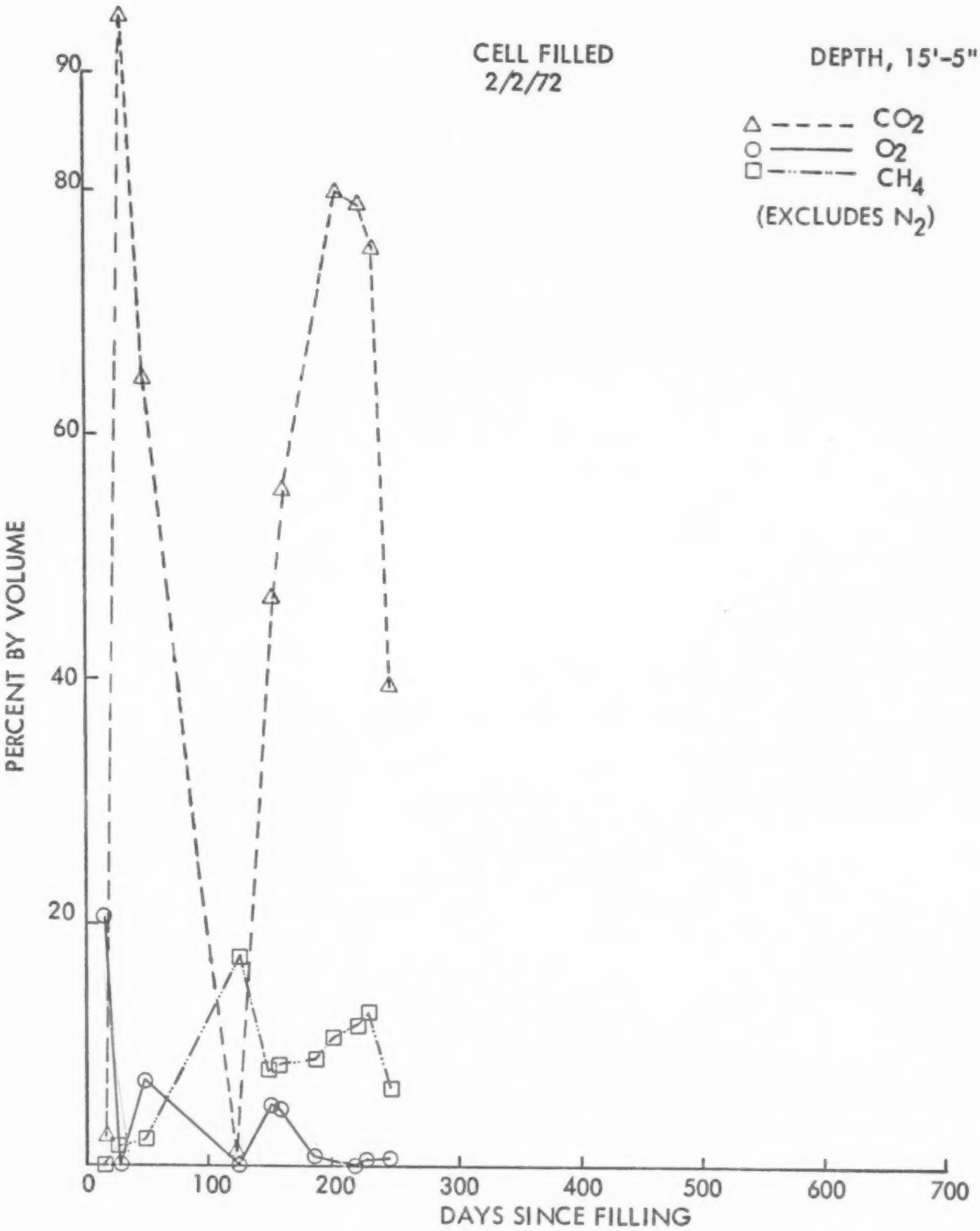


FIGURE VII-25

GAS ANALYSIS
TEST CELL 3

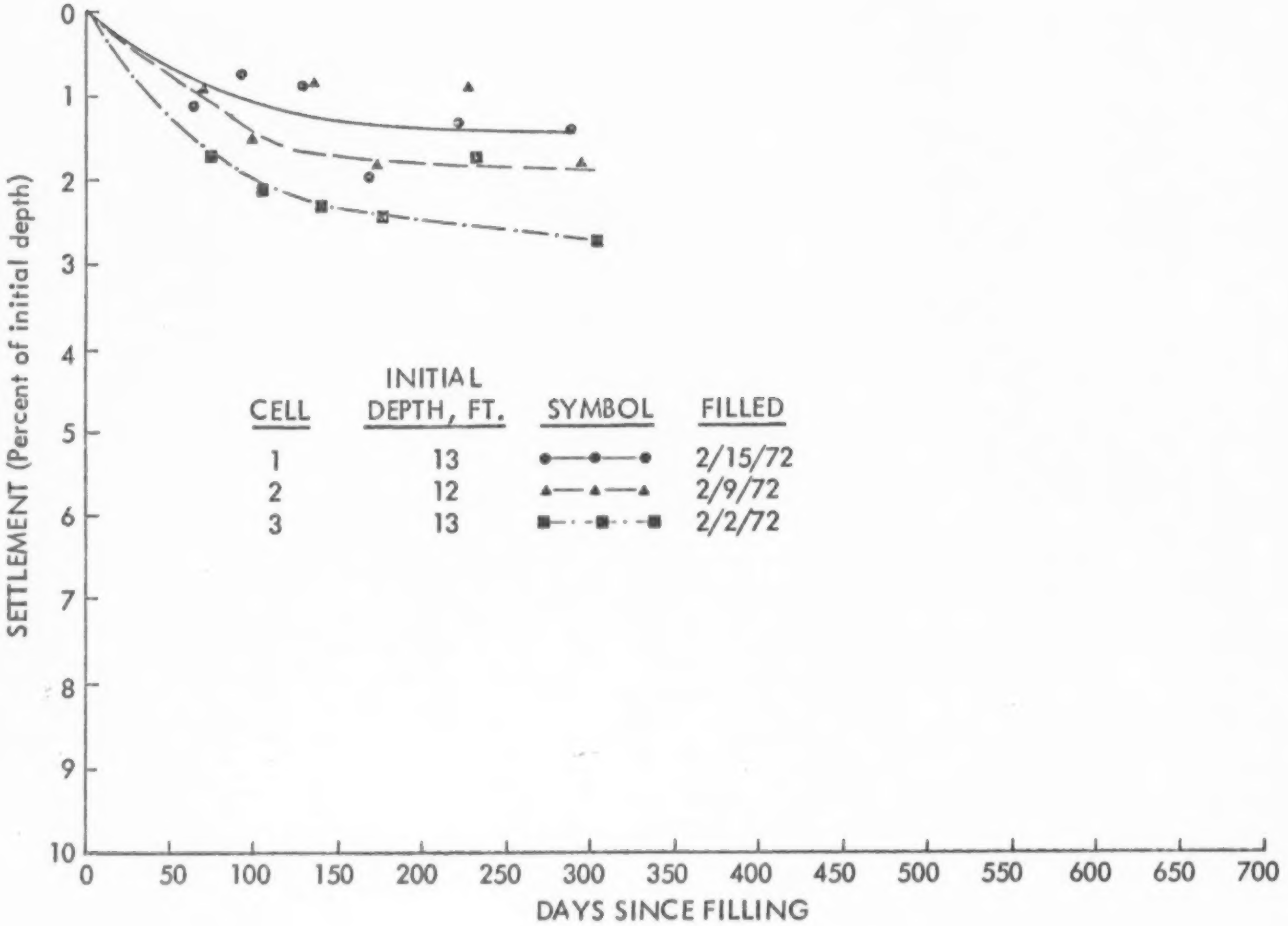


FIGURE VII-26
OCEANSIDE TEST CELL
SETTLEMENT

TABLE VII-10

TEST CELL 1 BORE HOLE TEMPERATURE PROFILE

	Depth, ft below soil surface	Temperature, deg F Days since filling was completed * 162	230	288
Ambient air		75	81	74
Soil	0	90	82	59
	2			
Solid waste/ sludge	4	94	87	73
	6	102	84	82
	8	104	84	84
	10	89	75	83
	12	103	83	83
Average +		98	83	81

* Cell filling completed February 15, 1972.

+ Average for solid waste/sludge.

TABLE VII-11

TEST CELL 2 BORE HOLE TEMPERATURE PROFILE

	Depth, ft below soil surface	Temperature, deg F Days since filling was completed * 168	236	294
Ambient air		75	80	76
Soil	0	86	82	67
	2	90		
Solid waste/ sludge	4	90	84	77
	6	90	83	
	8	92	82	81
	10	82	81	85
	12	84	86	79
Average +		88	83	80

* Cell filling completed February 9, 1972.

+ Average for solid waste/sludge.

TABLE VII-12

TEST CELL 3 BORE HOLE TEMPERATURE PROFILE

	Depth, ft below soil surface	Temperature, deg F Days since filling was completed * 175	243	301
Ambient air		78	83	78
Soil	0	72	82	67
	2	84		
Solid waste/ sludge	4	85	84	76
	6	90	85	82
	8	89	88	87
	10	87	86	85
	12	93	80	83
Average +		89	84	83

* Cell filling completed February 2, 1972.

+ Average for solid waste sludge.

the afternoon when higher air temperatures prevailed. The average temperature in each cell tended to follow ambient temperatures in the upper six feet of the cell fill; they decreased from July to November (first to third column). Temperatures in Cell 1 during July were significantly higher than in Cells 2 and 3 on the same day; on later samplings average temperatures were nearly equal in all three cells. Cell 1 received raw primary sludge which may have undergone more active bio-degradation than the digested sludges applied to Cells 2 and 3.

b. Organic Content. Organic analysis by depth are given in Tables VII-13 through VII-15. No trend is visible, thus variations in organic contents of the solid waste/sludge are attributable to sample variations. Of interest, however, is the cover soil organic content which increased significantly in the November samples. One week prior to sampling in November, 2.63 inches of rain fell, which probably provided a soil environment more hospitable for growth of organisms. The original cover soil was clean, inert fill with minimum organic content. Various yellow and reddish organisms were observed in proximity to soil cover cracks, which apparently developed using landfill gases as nutrients. The identity of the organisms was not established.

c. Moisture Content. Moisture content of corings from the three test cells are given in Tables VII-16 through VII-18. The cover soil moisture content increase in the November sampling indicates the effect of the previously mentioned rainfall. The average moisture content in all cells increased significantly after the rainfall compared to the previous samplings. Generally the moisture was greater in the lower part of the fill than on top - indicating some capillary movement as well as evaporation.

d. Moisture Absorption. Special laboratory tests to determine remaining moisture capacities were done on core samples from each cell having the highest and lowest moisture contents, and representative of organic contents. The results, given in Table VII-19, include the initial as-received sample moisture content, the moisture added to reach saturation and the total moisture content at saturation. The data is given in percent, which is convertible to lb water per lb dry weight solid waste when divided by 100. The additional moisture absorbed varied from 9.2 percent to 54.7 percent dry weight, which was well below the laboratory estimate of 60 percent minimum as-received absorptive capacity. All but two samples had final saturation values between 51 and 114 percent moisture content which corresponds well with the 60 to 180 percent saturation range estimated from the laboratory moisture absorption studies (see Table IV-6). The two samples below this range had considerably lower as-received moisture contents than all the other samples tested. Apparently the material in these two samples consisted of less absorbent solid waste constituents.

e. Core Sample Leachate BOD_5. The samples used in the moisture saturation tests described above were also used to generate leachate for BOD_5 analysis. The BOD_5 for the leachates are given in Table VII-20. The BOD_5 values dropped considrably during the 58-day period between the two core samplings.

TABLE VII-13

TEST CELL 1 CORE SAMPLE ORGANIC CONTENT

	Sample depth, ft below soil surface	Organic content, percent dry wt Days since filling was completed *		
		162	230	288
Soil	0	1.7	1.7	3.6
	2			
Solid waste/ sludge	4	38.0	32.6	75.2
	6	41.9	6.7	59.2
	8	18.4	44.7	55.8
	10	44.2	30.7	5.5
	12	20.4	37.7	34.3
Average +		32.6	30.5	46.0

* Cell filling completed February 15, 1972.

+ Average for solid waste/sludge.

TABLE VII-14

TEST CELL 2 CORE SAMPLE ORGANIC CONTENT

	Sample depth, ft below soil surface	Organic content, percent dry wt Days since filling was completed * 168	236	294
Soil	0	1.2	1.2	3.0
	2			
Solid waste/ sludge	4	33.5	22.0	26.3
	6	29.3	48.0	
	8	57.5	19.1	40.5
	10	36.6	66.5	22.4
	12	30.3	53.4	68.2
Average [+]		37.4	41.8	39.4

* Cell filling completed February 9, 1972.

[+] Average for solid waste/sludge.

TABLE VII-15

TEST CELL 3 CORE SAMPLE ORGANIC CONTENT

	Sample depth, ft below soil surface	Organic content, percent dry wt Days since filling was completed *		
		175	243	301
Soil	0	1.8	1.8	4.0
	2			
Solid waste/ sludge	4	22.8	76.0	65.7
	6	28.6	21.0	46.8
	8	34.0	61.3	86.8
	10	27.2	65.2	63.6
	12	38.9	56.5	51.1
Average +		30.3	56.0	62.8

* Cell filling completed February 2, 1972.

+ Average for solid waste/sludge.

TABLE VII-16

TEST CELL 1 CORE SAMPLE MOISTURE CONTENT

	Sample depth, ft below soil surface	Moisture content, percent dry wt Days since filling was completed *		
		162	230	288
Soil	0	7.6	7.6	9.5
	2			
Solid waste/ sludge	4	16.1	33.1	44.0
	6	19.2	15.0	46.0
	8	13.5	56.8	39.5
	10	28.4	46.8	70.5
	12	34.5	28.1	62.5
Average +		22.3	35.9	52.5

* Cell filling completed on February 15, 1972.

+ Average for solid waste/sludge.

TABLE VII-17

TEST CELL 2 CORE SAMPLE MOISTURE CONTENT

	Sample depth, ft below soil surface	Moisture content, percent dry wt Days since filling was completected * 168	236	294
Soil	0	3.8	3.8	11.7
	2			
Solid waste/ sludge	4	67.1	33.6	24.5
	6	38.0	42.1	
	8	24.2	17.8	44.0
	10	68.3	47.9	50.5
	12	69.0	27.0	58.7
Average +		53.3	33.6	44.4

* Cell filling completed February 9, 1972.

+ Average for solid waste/sludge.

TABLE VII-18

TEST CELL 3 CORE SAMPLE MOISTURE CONTENT

	Sample depth, ft below soil surface	Moisture content, percent dry wt Days since filling was completed *		
		175	243	301
Soil	0	9.8	9.8	12.9
	2			
Solid waste/ sludge	4	25.0	13.6	61.5
	6	46.3	43.3	46.0
	8	70.5	36.3	66.3
	10	92.1	52.5	32.2
	12	94.3	49.6	69.5
Average +		65.6	39.1	55.1

* Cell filling completed February 2, 1972.

+ Average for solid waste/sludge.

TABLE VII-19

MOISTURE ABSORPTION CAPACITY OF SELECTED CORE SAMPLES

	Moisture content, percent dry wt * Days since filling completed/depth, ft				
	230		288		
Cell 1	4	8	6	8	10
Sample moisture content	15.0	46.8	39.5	70.5	62.5
Additional moisture absorbed	9.2	54.7	30.6	11.8	51.7
Total moisture at saturation	24.2	101.5	70.1	82.3	114.2

	236		294	
Cell 2	6	8	3.5	10
Sample moisture content	17.8	47.9	24.5	58.7
Additional moisture absorbed	21.2	39.2	26.7	50.4
Total moisture at saturation	39.0	87.1	51.2	109.1

	243		301	
Cell 3	6	8	8	9
Sample moisture content	36.3	52.5	32.2	69.5
Additional moisture absorbed	15.0	51.3	23.2	27.8
Total moisture at saturation	51.3	104.8	55.4	97.3

* Percent dry wt is equivalent to lb of water per 100 lb of dry wt solid waste.

TABLE VII-20
BOD$_5$ OF LEACHATES FROM SELECTED *TEST CELL CORE SAMPLES

Cell 1			Cell 2			Cell 3		
Days since filling	Depth ft	BOD$_5$, mg/l	Days since filling	Depth, ft	BOD$_5$, mg/l	Days since filling	Depth ft	BOD$_5$ mg/l
230	4	680	236	6	660	243	6	170
	8	1,170		8	4,250		8	3,070
288	6	106	294	3.5	28	301	8	138
	8	133		10	92		9	67
	10	561						

---

* Samples used to determine moisture absorption were leached to obtain about 157 ml of leachate for BOD$_5$ analysis.

f. Bacteriological Analysis. During the July 2, 1972 core sampling, core samples at the 4 and 10-foot depths were taken in sterile containers using aseptic collection techniques. Analyses made in duplicate for fecal coliform, fecal streptococci and Pseudomonas aeruginosa on these samples are presented in Table VII-21. The analyses detected fecal coliform and pseudomonas at 4-foot depths, and none at 12-foot depths. No fecal streptococci were detected at either depth. One hypothesis for the difference in results between the 4 and 12-foot depths is that the test cell environment at 4 feet may be aerobic, and at 12 feet anaerobic. The absence of fecal streptococci may be due to a lack of fecal material in the samples or a shorter survival time (sampling occurred 5.5 months after sludge and solid waste placement). Also, the core samples were extracted for analysis in liquid form; the sample extract appearance for 4-foot depths was earthy yellow, and blackish grey for 12-foot depths.

These results are similar to findings in another report[26] on bacteria survival in soil. Coliform bacteria were reported to be seldom found below 4-foot depths in soil, and were never found below 7 feet.

g. Odor. Odor was determined in terms of strength and type at each 2-foot core sample depth. Odors were generally strong to moderate on the first core sampling (July 1972), and then became moderate to weak on the two subsequent core samplings. Odor in Cell 1 was predominantly strong, and was stronger than for Cells 2 and 3 on the first sampling. This was attributed to the more oderiferous raw primary sludge placed in Cell 1. No difference in odor strength was detected on subsequent samplings.

The type of odor predominating during the first borings was a strong, sweet, septic condition in Cell 1 and putrid, pig pen, or normal landfill in Cells 2 and 3. Odors in subsequent samplings were identified as strong sour smells in all cells.

h. Core Sample Appearance. Appearance of samples was observed to be agglomerated when highly moist and when mixed with large quantities of sludge. The agglomerated material required a screwdriver or similar probe to remove strongly adhering samples from the large 12 inch diameter auger drill bit. The majority of the samples were moderately to highly agglomerated in all three cells each time they were sampled. Occasionally, lumps of moist sludge were identified in the solid waste.

i. Color. Colors in metals, plastic, rubber, glass, ceramics, leather, textiles and wood were similar to those originally disposed except that they were obviously dirty. Paper appeared unchanged in all three cells during the first sampling, but was faded or bleached white in Cells 1 and 2 in subsequent samplings. Grass, leaves, tree and shrub prunings rate of decomposition varied considerably between samples; there was no consistent pattern. Vegetation colors observed included light to dark green, faded green, faded yellow, yellowish-green, yellowish-brown and brown.

j. Readability. The core samples were observed to see if printed paper and container labels were readable. In general, newsprint, and paper printing, glass, metal and plastic labels were readable. Wet paper with printing tended to be blurred. No variations between cells or depth were detected.

TABLE VII-21

SUMMARY OF BACTERIOLOGICAL ANALYSIS OF TEST CELL SAMPLES

Sample			Standard plate count per gram	Fecal coliform		Pseudomonas aeruginosa		Fecal Streptococci		Appearance of sample extract
Test cell B.H.*, no.	Depth, ft	Replicate		MPN/g	%	MPN/g	%	MPN/g	%	
1	4	A	3.0×10^6	3.3×10^2	.011	40	≈0	<0.2	0	Earthy
		B	2.0×10^6	3.3×10^2	.017	70	≈0	<0.2	0	yellow
1	12	A	1.4×10^5	<0.2	0	<0.2	0	<0.2	0	Blackish
		B	1.3×10^5	<0.2	0	<0.2	0	<0.2	0	gray
2	4	A	2.0×10^7	9.2×10^4	0.46	2.4×10^3	.012	<0.2	0	Earthy
		B	1.8×10^7	5.4×10^4	0.3	2.4×10^3	.013	<0.2	0	yellow
2	11	A	1.3×10^6	<0.2	0	<0.2	0	<0.2	0	Blackish
		B	1.4×10^6	<0.2	0	<0.2	0	<0.2	0	gray
3	4	A	7.5×10^6	4.6×10^2	.0061	3.3×10^2	.0044	<0.2	0	Earthy
		B	8.0×10^6	4.6×10^2	.0058	3.3×10^2	.0041	<0.2	0	yellow
3	12	A	4.0×10^6	<0.2	0	<0.2	0	<0.2	0	Blackish
		B	3.0×10^6	<0.2	0	<0.2	0	<0.2	0	gray

Note: Any piece of paper in all samples shredded into tiny fibers of cellulose upon manual shaking in dilution bottles.

* B.H. = Bore hole number

k. Biodegradability. During the first sampling, the sample materials were observed to be none or slightly degraded. In subsequent samplings, the core materials were observed to be none to moderately degraded. Food wastes were detected in about 10 percent of the samples, and consisted of fruit peelings and isolated fragments. The peelings were not noticeably degraded.

6. Comparison of Sludge Admixed Solid Waste With Normal Solid Waste. The three field test cells (lysimeters) at Oceanside closely simulate conditions in a landfill. Other studies on large test cells under conditions comparable in scope and data collected were conducted by Ralph Stone and Robert C. Merz during 1964-1966 at the Los Angeles County Sanitation District's Spadra Landfill in Walnut, California.[27] Three test cells were initially constructed, one of which simulated a golf course irrigation, the second simulated heavy (Seattle, Washington) rainfalls, and the third which was aerated. The Spadra cells were larger in size (19-foot depth of solid waste, two-foot soil cover, and 70-foot by 130-foot in surface area) than the Oceanside cells. They were in a similar climate, and therefore suitable for comparison with Oceanside test cell data. Data from the two anaerobic Spadra cells will be used for comparison.

A study by Fungaroli[28] on landfill leachate pollution of subsurface water consisted of monitoring a laboratory lysimeter and landfill test plot in Pennsylvania during the period 1966 through 1968. The landfill test plot contained eight feet of solid waste, a two-foot soil cover, and was 50 feet by 50 feet in surface area (similar in size to the Oceanside cells). This test plot provides comparative data for different (Pennsylvania) climatic conditions.

Data from other landfills studied by Ralph Stone and Company, Inc., will also be cited for comparison.

A summary of landfill leachate analyses from several literature sources is used for comparative discussions of leachate quality.

a. Leachate Generation. The quantity of leachate obtained from the Oceanside test cells and estimated quantity of rain into the cells was shown on Figures VII-5 through VII-8. The insignificant amount of leachate obtained during the first 300 days since filling is similar to results reported by Fungaroli. During the first 400 days, he obtained 17 gallons of leachate which was significantly less than the 383 gallons of water added to his lysimeter. The initial moisture content of Fungaroli's lysimeter was 26.6 percent wet weight (36.2 percent dry weight), which was in the range for the three Oceanside field test cells. The leachate obtained from Oceanside test cells as a percentage of total moisture (solid waste moisture plus liquid in the sludge) was for Cell 1 - 0.07 percent, for Cell 3 - 1.9 percent, and for Cell 2 - zero. This is less than the 4.4 percent leachate recovered from water added to solid waste by Fungaroli. The ratio's of weight of water added to dry weight of solid waste were: Fungaroli - 2.9; Cell 1 - 0.45; and Cell 3 - 0.71. This accounts for the greater percentage of leachate obtained by Fungaroli. Fungaroli attributed leachate production to the following landfill behavior characteristics.

1). Leachate from Solid Waste - The source is moist organic matter and other liquids in the waste released by decomposition and compaction.

2). Leachate from Channeling - Water running through interstitial channels thus short-circuiting the absorption mechanism.

3). Differential Advancement of the Wetting Front - The more absorptive areas of solid waste become saturated with moisture and then leachate may develop before the entire waste fill is saturated.

4). Saturated Wetting Front - When the entire waste fill reaches field moisture saturation capacity, water application and leachate quantities then become nearly equal.

It was probable that leachate from the Oceanside Cell 1 resulted from a combination of sludge/waste initial moisture and sludge channeling, and that leachate from Cell 3 resulted from subsequent differential settlement enabling rainfall drainage channeling to occur.

The leachate production from sludge admixed solid waste does not appear to differ in mechanism or quantity from that of normal solid waste leachate without sludge.

b). Leachate Characteristics. The range of landfill leachate characteristics reported from 11 landfills and lysimeters in California are given in Table VII-22. The climatic conditions and solid waste characteristics of the landfills in Table VII-22 are somewhat similar to those in Oceanside and will therefore serve as the primary basis of assessing the effects of sludge admixture. The Sonoma cells in Table VII-22 received high quantities of water, and septic tank pumpings and therefore should behave similar to the Oceanside test cells.

The range of pH values for landfill leachates given in Table VII-22 (excluding Sonoma) is 5.6 to 7.8, and for Oceanside Cells 1 and 3 the leachate pH ranged from 4.6 to 5.9. The Sonoma cells leachate pH value was also low (4.6 to 6.5). It appears that admixing sewage sludge (and septic tank pumpings) into solid waste can produce a more acidic leachate. The ages of the fills which data in Table VII-22 covers varies considerably from the age of the Oceanside test cells. Fungaroli reported lysimeter leachate studies at Drexel University with a fill age similar to the Oceanside cells. He obtained leachate pH values in the range 5.1 to 7.1. This agrees with the above higher pH values for normal landfills. The pilot test drum leachate analyses (see Section VI.C.7) agree with these results.

The range of BOD_5 values for leachate from normal landfills given in Table VII-22, except for the high range at Riverside, is significantly lower than the Oceanside Cells 1 and 3, and the Sonoma cells.

TABLE VII-22 SUMMARY OF LANDFILL LEACHATE CHARACTERISTICS

Leachate Components	Landfill site location			
	Riverside Landfill* (Bin #1)	Scholl Canyon Landfill+	Puente Canyon Landfill+	
			(2-13-62)	(3-5-62)
pH	5.60-7.63	7.1-7.8	6.0	7.2
BOD (5 day)	81-33,100	97-1200	2200	9200
Nitrogen - Kjeldahl	2.4-550			
Copper		3.3-24		
TDS		1452-2664	18,154	12,530
Alkalinity ($CaCO_3$)	730-9500	1259-2516	3260	5730
Calcium	115-2570	95-567	1340	560
Chloride	96-2350	67-344	1100	1330
Hardness ($CaCO_3$)	650-8120	1085-2075	5600	3260
Iron - Total	6.5-305	5.4-260	135	150
Lead		3.3-5.0		.125
Magnesium	64-410	30-265	547	455
Manganese		200-1400	18	13
Nitrogen - NO_3		0-4.0	4.5	
Potassium	28-1860	6.5-13	340	700
Sodium	85-1805	87-115	620	810
Sulfate	39-730	1.0-40	1370	
Total Phosphate	.16-29			
Zinc		20-1000		20

Note: All figures in mg/l unless otherwise noted on Page 202. Footnotes explained on Page 202.

TABLE VII-22 SUMMARY OF LANDFILL LEACHATE CHARACTERISTICS (cont.)

Leachate Components	Mission Canyon Landfill[#]		Landfill site location Central Disposal Site, Sonoma, California[**]				Range of Values
	3-18-68	3-24-71	Cell B	Cell C	Cell D	Cell E	
pH	5.75	7.4	4.2-4.5	4.9-5.2	4.6-5.2	5.8-6.5	4.2-7.8
BOD (5 day)	10,900	908	13,500-32,400	14,700-28,200	19,800-33,600	1020-1730	908-33,600
Nitrogen - Kjeldahl	104	92.4	20-170	174-800	182-864	350-558	2.4-864
Chloride	660	2355	998-1800	530-1200	920-1210	170-210	67-2350
TDS	44,900	13,409	15,970-42,270	9180-19,336	14,196-21,010	2186-2948	1452-44,900
Alkalinity ($CaCO_3$)	9860	8677	0-2360	0-5480	3050-5950	626-704	0-9860
Calcium	7200	216	200-2950	700-1600	900-1800	170-200	81-2950
Copper			3.6	0-0.6	0-0.4	.45	0-24
Hardness ($CaCO_3$)	22,800	8930					650-22,800
Iron - Total	2820	4.75					4.75-2820
Lead			3.0	0-0.8	0-2.0	2.0	0-5
Magnesium	15,600	8714	320-924	200-760	360-600	120-150	30-15,600
Manganese							13-1,400
Nitrogen - NO_3			2.5-66	1.8-4.6	1.90-6.34	.87-1.0	0-66
Potassium	68	440	1500	560-845	727-910	24	6.5-1860
Sodium	767	1160	1325	550-950	860-1020	115	85-1805
Sulfate	1190	19		340-880	794-1040		1-1370
Total Phosphate	.24	.65	0-83	9.8-41.9	17.8-79.2	.35-2.3	0-83
Zinc			140	22-42	30-95	.15	0.15-1000

Note: All figures in mg/l unless otherwise noted on Page 202. Footnotes explained on Page 202.

TABLE VII-22 FOOTNOTES

*Report on the investigation of leaching of a sanitary landfill. California State Water Pollution Control Board Publication No. 10. Sacramento, 1954. 92 p.

+Sanitary landfill studies; Appendix A; summary of selected previous investigations. California Department of Water Resources Bulletin No. 147-5. Sacramento, The Resources Agency, July 1969. 115 p.

#Meichtry, T. M. Leachate control systems. Presented at the Los Angeles Regional Forum on Solid Waste Management, May 25, 1971.

**Central Sonoma County sanitary landfill [test cells demonstration grant]. U.S. Environmental Protection Agency demonstration grant no. G06-EC-00351, 1971.

The quarterly comprehensive analyses of leachate from Oceanside Cell 1 taken two months after filling is given in Table VII-7. The Oceanside Cell 1 analyses show values of copper, iron (total), lead, and manganese generally well below the lower limits of the data ranges for landfills shown in Table VII-22. Values of other leachate components showed no discernible difference. The low value noted for iron indicates that the Oceanside Cell 1 pH value of 6.1 (Table VII-7) was too great for ferric ions to remain in solution. Fungaroli's data showed little iron or copper in leachate during the first 110 to 120 days after filling (analyses were not made for lead and manganese). Also, the relatively young age of Cell 1 and the small quantity of leachate may not have provided sufficient opportunity and liquid carrier to dissolve large quantities of metals into solution.

c.) Gas Composition. A comparison of gas composition in the Oceanside test cells with gas compositions reported by Merz and Stone is given in Figure VII-27. The CO_2 trends are quite similar, but CH_4 concentrations in the Oceanside test cells lag the concentrations reported by Merz and Stone. An extension of the Oceanside trend indicates that it should coincide with the Merz and Stone trend at about 350 days after filling. The gas concentrations in the Oceanside test cells appear to follow typical trends for normal landfills. Fungaroli obtained similar patterns, but significantly lower concentrations: CO_2 increased to 45 percent at the lysimeter bottom and to 75 percent at mid-depth within 40 days after filling, and then decreased to 15 and 30 percent, respectively. Fungaroli obtained little CH_4, generally less than one percent by volume.

d.) Temperature. Initial peak temperatures in landfills have been shown to be a linear function of the solid waste (and weather) temperature at the time of placement of the solid waste. This relationship, as illustrated by Farquhar, is given in Figure VII-28, which shows the Oceanside test cells and the Spadra (California) cells. The three Oceanside test cells fit the landfill temperature curve well, thus indicating that the liquid sewage sludge did not significantly affect the peak temperature behavior. Comparisons of temperature trends in the Oceanside test cells with the Merz and Stone Spadra cells are given in Figures VII-29 and VII-30. The temperature trends from the Oceanside cells are converging with the trends reported by Merz and Stone.

e.) Settlement. A comparison of surface settlement trends as a percentage of initial depth is given in Figure VII-31 for the Oceanside and Spadra test cells. Settlement rates in the Oceanside cells were greater than in the Spadra cell during the first 100 days after filling. These different initial settlement rates are attributable to the original differences in the density of the Oceanside cells (623 to 640 lb per cu yd). and the Spadra cell (1,200 lb per cu yd). The total settlement during the first 300 days for the Oceanside and Spadra cells were all within the range of 1.3 to 2.8 percent of initial depth. A review of landfill settlement at Coyote Canyon landfill in Orange County, California (about 30 miles north of Oceanside) indicated average annual settlements of 1.0 to 1.1 percent. Compaction density at Coyote Canyon is reported to be 1200 lb per cu yd, which is identical to the Spadra cell. The Spadra cell

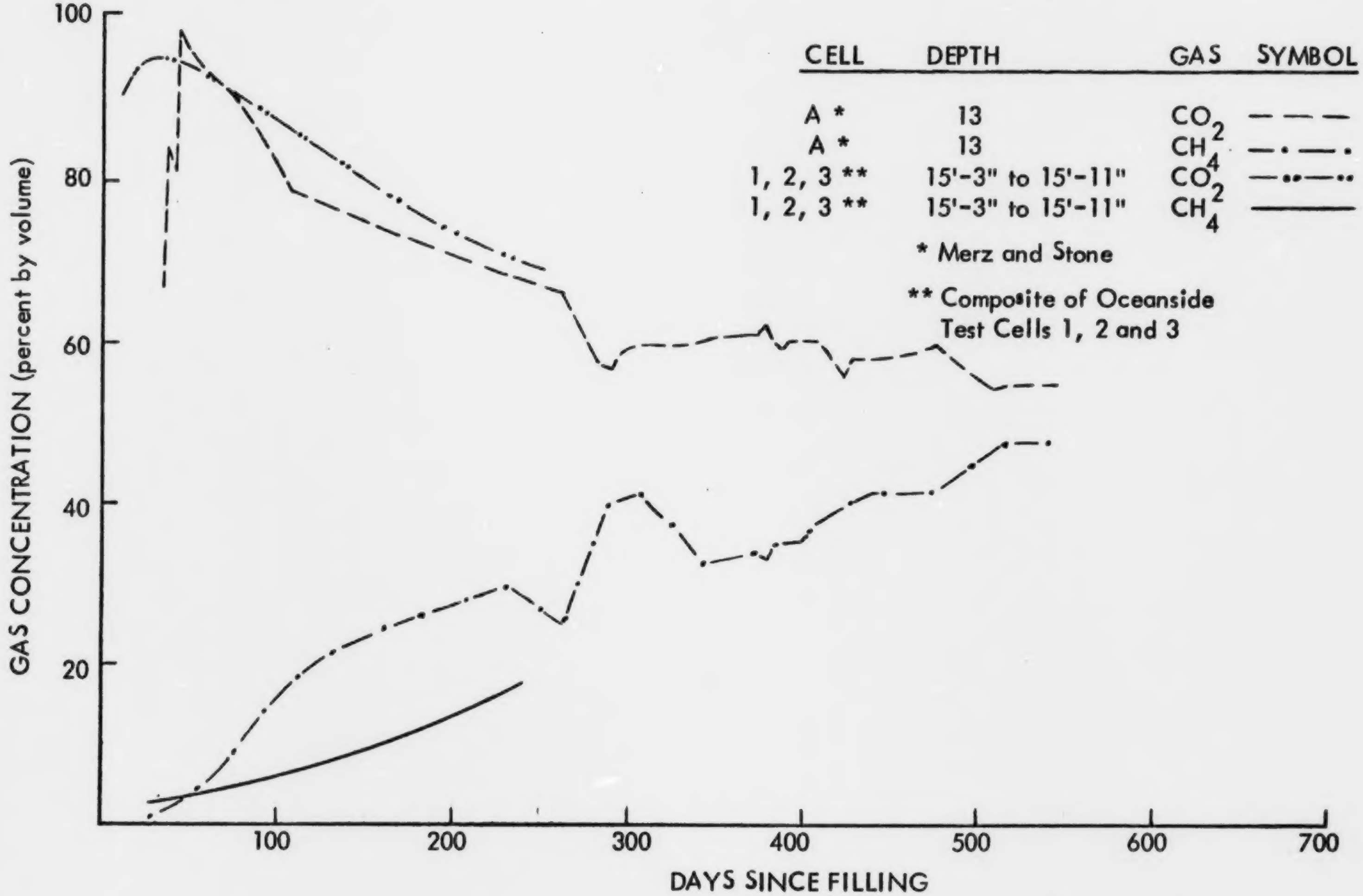
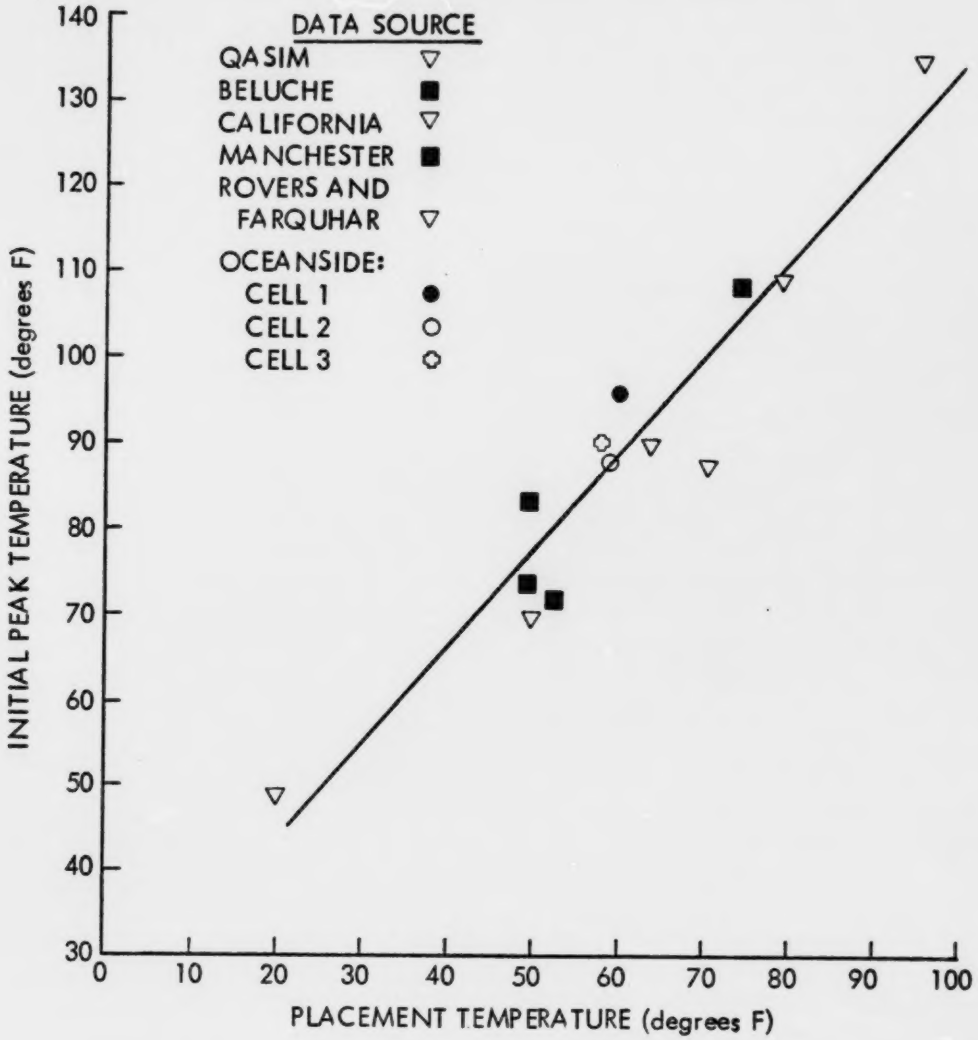


FIGURE VII-27
COMPARISON OF GAS
COMPOSITION IN OCEANSIDE
TEST CELLS WITH NORMAL SOLID WASTE



SOURCE: Farquhar, G. University of Waterloo, Department of Civil Engineering, Waterloo, Canada, presented at Engineering Foundation Conference, 1972.

FIGURE VII-28
RELATIONSHIP BETWEEN INITIAL PEAK TEMPERATURE AND PLACEMENT TEMPERATURE

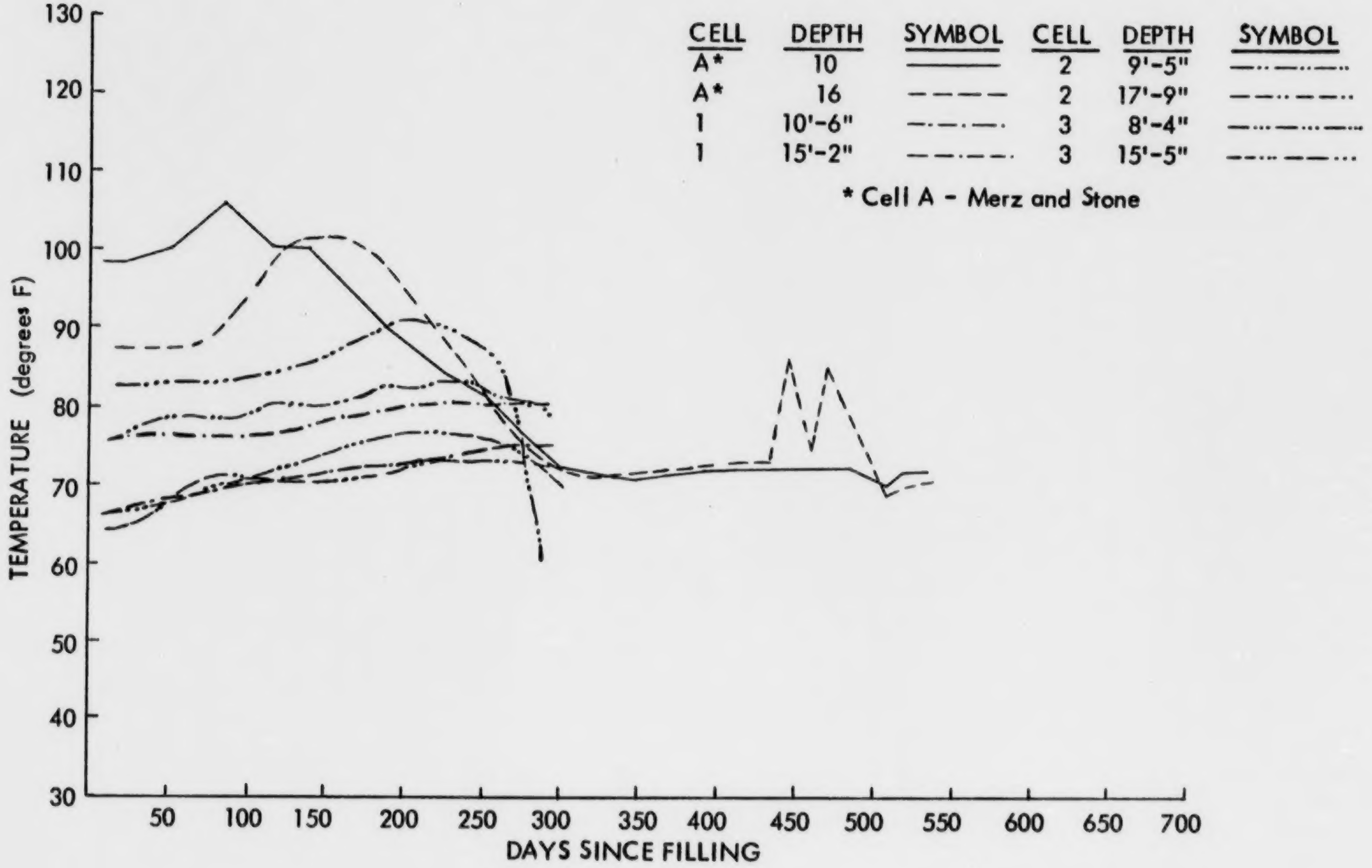


FIGURE VII-29
COMPARISON OF
TEMPERATURES

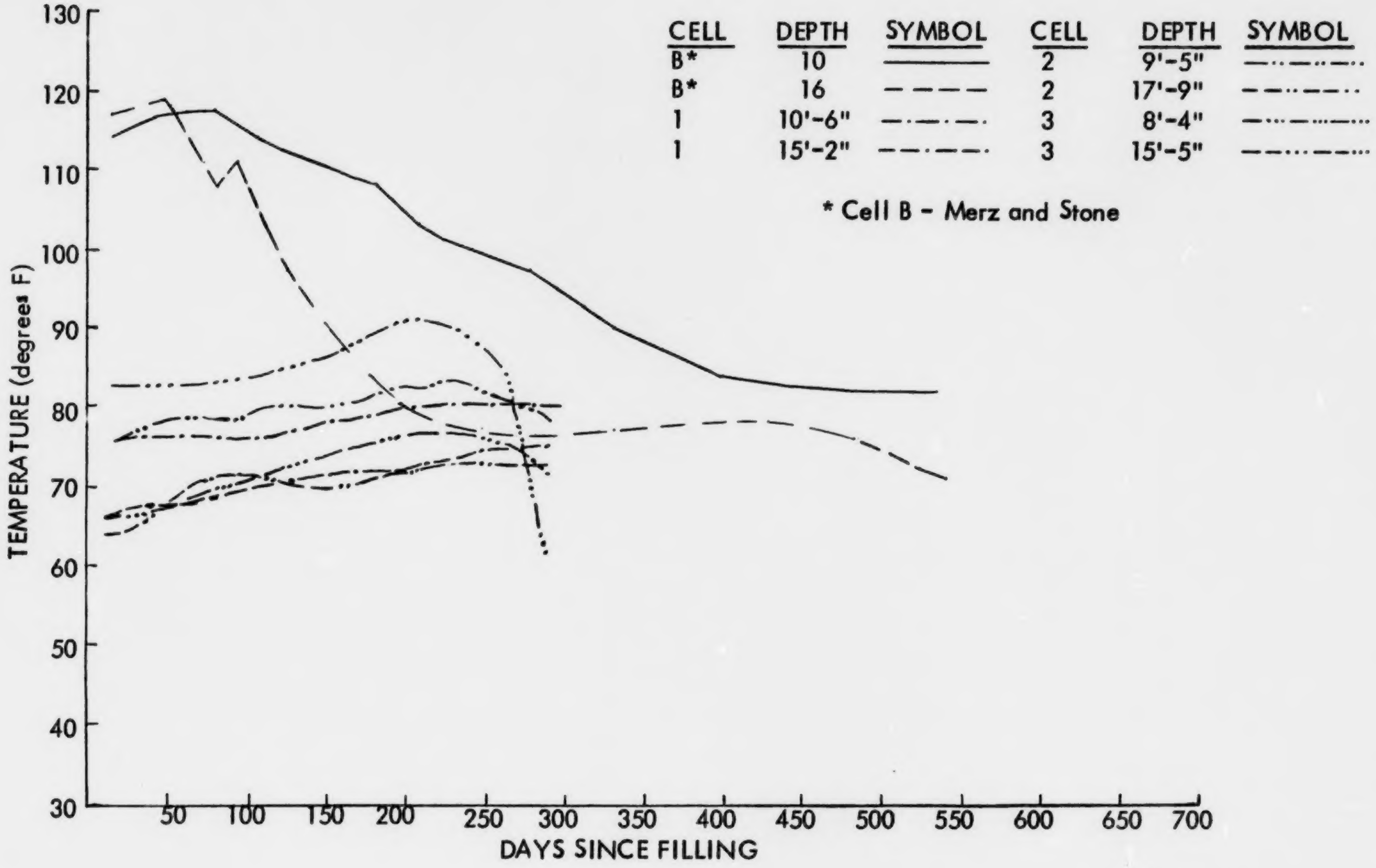


FIGURE VII-30
COMPARISON OF
TEMPERATURES

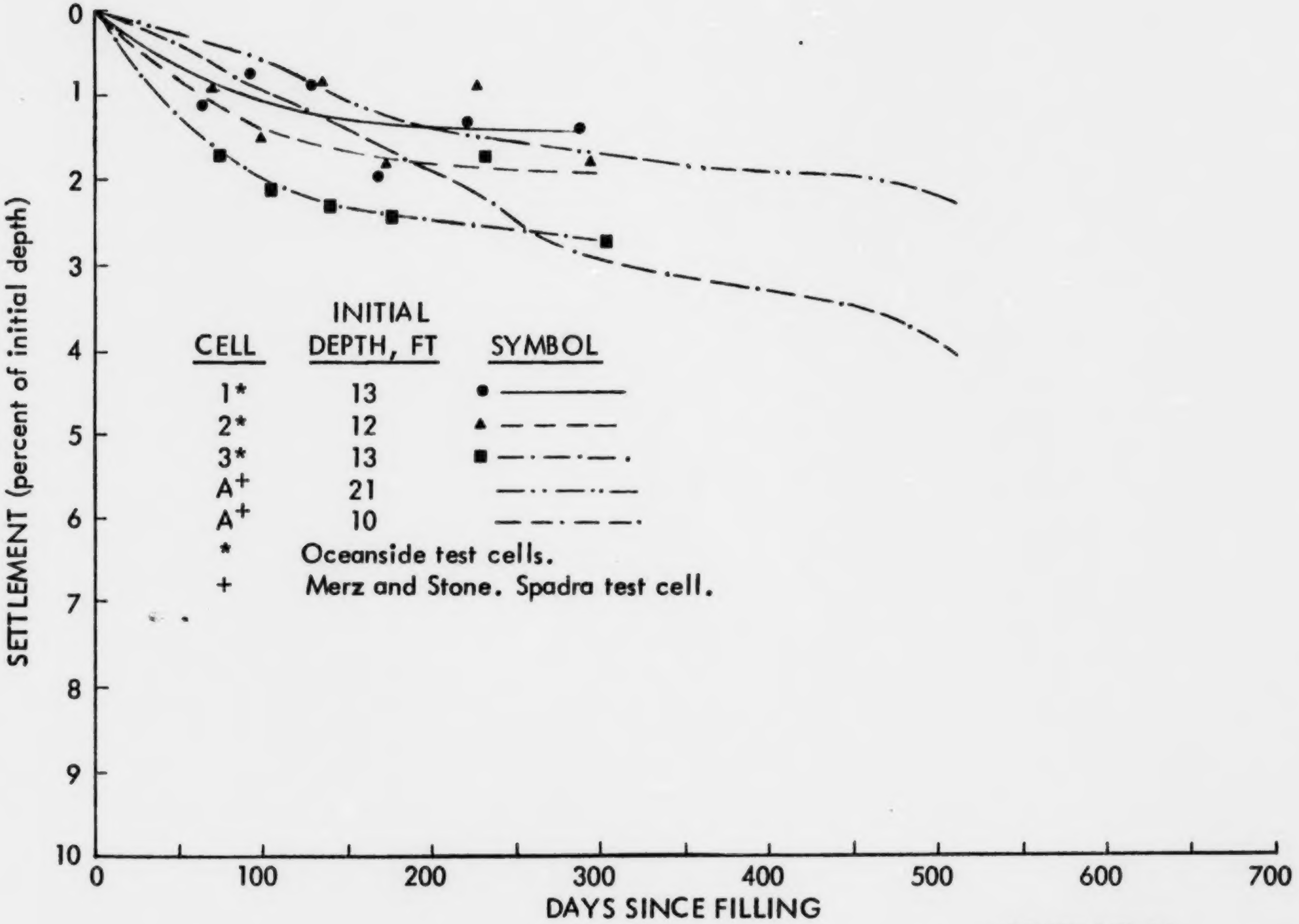


FIGURE VII-31
COMPARISON OF SETTLEMENT
OCEANSIDE TEST CELLS AND NORMAL
LANDFILL CELLS

received water at a rate triple the normal rainfall experienced at Coyote Canyon, thus the higher settlement at Spadra resulted.

f.)Summary. The significant differences noted between sludge admixed with solid waste (Oceanside cells) and normal landfills were that sludge admixed waste had lower leachate pH, higher leachate BOD5 values and higher Kjeldahl organic nitrogen. The higher BOD5 values of Oceanside test cell leachate could be attributable to a high soluble organic content in the liquid sewage sludges admixed into the test cell solid waste. The moist or dried sludge organics would be readily soluble in rainfall or other liquid passing through the fill. The higher Kjeldahl organic nitrogen in the Oceanside cell leachate obviously resulted from the high concentration of nitrogen compounds and ammonia in the sludge.

The lack of significant short-term differences in temperature, settlement and gas composition between sludge admixed solid waste and normal landfill solid waste indicates that the effects of the sludge on these parameters are minimal. Additional monitoring to be completed during Year 03 will further differentiate any effects of the sludge on landfill behavior.

VIII. FIELD DEMONSTRATION OF LANDFILL OPERATIONS AND LIQUID SLUDGE DISPOSAL

A. Purpose

The disposal of liquid digested sewage sludge into a sanitary landfill may not only create certain environmental difficulties but it may also present certain operational opportunities and challenges. Operational aspects to be considered are related to equipment, personnel, landfilling methods, soil cover techniques, compaction, drainage, leachate discharge, gas generation, etc. Landfill environmental nuisances which must be controlled include odors, litter, dust, flies (and other insect vectors), birds, rats (and other vermin), and fires.

The operational aspects of sludge disposal into a sanitary landfill were evaluated in special demonstration field studies conducted at the Oceanside landfills. These studies have not yet been completed and are expected to continue through the remaining third year of the present 3-yr program. The results which have been obtained and the problems observed to date are presented and discussed in the following text. Site geology, soil and groundwater conditions are described in Appendix G.

B. Method of Study

1. Landfill Site. The preliminary landfill studies were conducted in a selected area at the old Oceanside sanitary landfill. These preliminary studies with liquid sludge were initiated in May 1971 and were continued through November 15 at which time the City closed its old landfill site and opened a new landfill site. The field study was interrupted for three weeks until sufficient deposited solid waste spreading area became available at the new landfill site. In February 1972 (at the start of the second year demonstration program), the City commenced disposing of all digested liquid sewage sludge generated at its three treatment plants into the municipal landfill. This full-scale demonstration operation permitted a comprehensive evaluation of the practical aspects of liquid sludge-solid waste landfill disposal.

2. Parameters Evaluated. The parameters evaluated in the field tests included: sludge and solid waste composition, sludge application techniques, solid waste fill/sludge admixture, personnel, equipment operation and maintenance, odors, gas emissions, blowing of litter and dust, presence of flies, birds, rats, and other vectors and waste bio-degradation. Table VIII-1 is a summary of the landfill operation monitoring. The landfill monitoring data sheets are shown in Appendix B. A brief description of the various tasks performed through June 1972 is presented. A sample of seagulls at the landfill is shown in Photograph VIII-1a.

The sludge application methods evaluated included the use of different spreading techniques, application of different weight ratios of sludge to solid waste,

TABLE VIII-1
LANDFILL OPERATIONS MONITORING SCHEDULE

Task	Frequency	Performed by
Performance:		
time and motion studies	Weekly	Ralph Stone and Company, Inc.
analysis of sludge application effects	Weekly	
Landfill equipment O & M (time)	Weekly	Waste Disposal Department*
Environmental effects:		
blowing litter and dust, odor, flies, vermin, birds	Daily	Waste Disposal Department*
operating hazards	Weekly	Ralph Stone and Company, Inc.
Waste core samples (moisture content, decomposition)	Quarterly	Ralph Stone and Company, Inc.
Sludge Application studies:		
spreading sludge with and without soil and refuse cover	Continuously during the year	Waste Disposal and Sewer Depts.*
spreading sludge on compacted/ uncompacted waste	Continuously during the year	Waste Disposal and Sewer Depts.*
evaluations of different methods sludge application (pumping, gravity feed, single nozzle hose, splash plates, etc.)	Continuously during the year	Ralph Stone and Company, Inc.
Temperature, gas sampling (H_2S)	Periodically during landfill studies	Sewer Department* and Ralph Stone and Company, Inc.

---

*City of Oceanside municipal departments.

a. SEA GULLS FORAGING ON SLUDGE-FREE SOLID WASTE.

b. TRUCK APPLYING LIQUID SLUDGE TO FLAT TEST AREA. NOTE SPREADING PLATES.

c. DOZER MOVING SLUDGE/WASTE ADMIXTURE.

PHOTOGRAPH VIII-1

INITIAL SLUDGE - SOLID WASTE FIELD TESTS and deposition of various thicknesses of sludge on different solid waste landfill surfaces. Relatively simple, inexpensive methods for spreading trucked sludge over solid waste were demonstrated using direct discharge from the transportation truck. These were: gravity flow from a single 4-in. diameter pipe, gravity flow from similar piping using single and double splash plates, mechanical pumping through a standard fire hose to improve distribution and gravity flow from a 4-in. diameter flexible hose mounted on an 8-foot boom.

The effect of fill construction on sludge handling capacity was evaluated through: a) application of liquid sludge to uncompacted and compacted waste, and completed landfill, b) varying the slope of the fill surface from 1:2 to level, and c) building up the waste and earth cover into dikes to pool the sludge so that the solid waste could be directly discharged into the sludge pool. The effects of excessive moisture were determined by conducting operating tests during rainfalls.

Landfill equipment studies involved reviewing the records for operation and maintenance of the landfill tractor dozers. The City of Oceanside Waste Disposal Department operates two tractor dozers with straight buckets at its landfill, a CAT 977 and a 977 K. The 977 K serves as a backup. Random time and motion studies were conducted to determine the efficiency of the dozer in working the solid waste-sludge mixture under various disposal methods used. The major operating parameters considered were traction and load moving capability on the waste fill surface. Samples of equipment data sheets used in the field are presented in Appendix B. In addition to monitoring dozers, tests were made to evaluate the driving performance of a rubber-tired sludge tank truck while spreading sludge on the fill surface. In order to determine the effects of admixing sludge into solid waste on personnel health and safety, records of illness and accidents from the City of Oceanside were analyzed.

3. Filling and Spreading Operations. The demonstration operations at the old landfill consisted of an initial trial run and a subsequent "extended" operation. In the trial run, three truck loads of solid waste (about 25,000 lb) were unloaded in a flat section at the foot of the landfill working face. The wastes were worked by a CAT 977 K tractor dozer to a 1.5 foot depth within a 60 by 80 foot diked rectangular test area. A 1,250 gallon rubber-tired tank truck was used to apply the secondary digested sludge from the Buena Vista treatment plant by gravity feed through a double nozzle splash plate. The ratio of 1,250 gallons of sludge to three truck loads of waste was slightly less than the proportion in which these wastes are generated in Oceanside (1,750 gallons of liquid sludge per three truck loads of solid wastes). Photographs VIII-1b and c show sludge application and waste/sludge working.

The "extended" field demonstration operation was conducted for seven months at the old landfill and for two months at the new landfill. A total of 30 days (about one per week) of sludge disposal operations were made, 11 of which were at the new landfill. During the tests, the temperature ranged from a low of 46 F to a high of 92 F and the wind intensity ranged from "calm" to "moderate". The temperature remained above 70 F until October 26, 1971; thereafter it was 70 F or lower until the end of the test program in January 1972. During this period, only one day of rainfall occurred when liquid sludge was disposed.

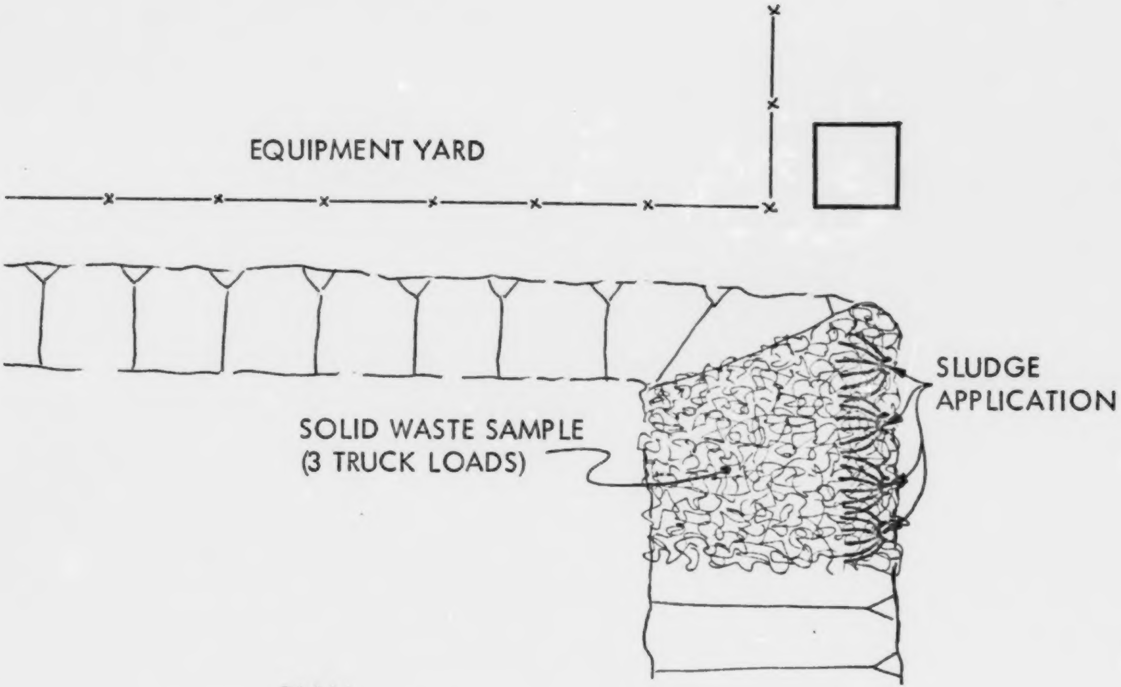
Initially, 1,250 gallons of sludge and two truck loads (32 cu yd capacity) of solid waste were applied to the test site once every week. After an additional two weeks, the weekly demonstration quantities were increased to 1,750 gallons of sludge and three truck loads of solid waste. These quantities were further increased to 3,500 gallons of sludge and six truck loads of solid waste per week.

Figure VIII-1 schematically describes the solid waste placement and sludge application. The solid waste was unloaded at the top of the fill slope, pushed onto the face of the slope, and worked by the dozer to a depth of about 2 ft. A variation of this procedure was also tested. It consisted of pushing the waste onto the slope without working to compact it. In all cases, the sludge was applied evenly across the top of the slope. A daily soil cover of about 6 in. was applied to the fill slope and a 1- to 2-ft soil cover was provided at the top of the slope on the flat portion of the fill lift.

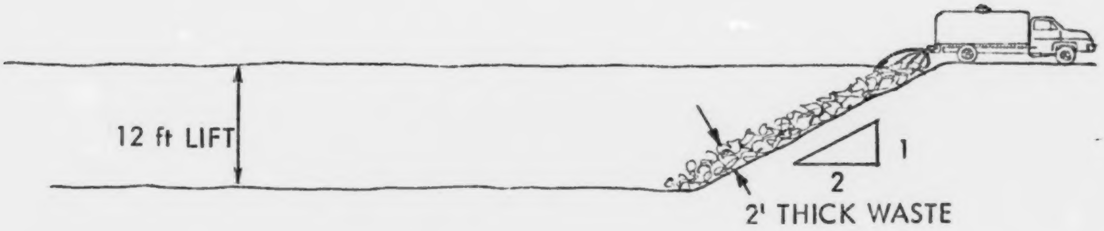
During the full scale operation at the new landfill site, sludge handling was initially on a two-day per week basis. This was later increased first to three days per week, and then to five days per week. During the test period, the temperature ranged from 60 F to 78 F, the wind intensity varied from "calm" to "moderate," and showers occurred on four days. Other information pertaining to the operation at the new landfill is discussed below in connection with the results.

4. Core Sampling. Quarterly bore hole drilling was completed at the existing Oceanside demonstration landfill in areas representing three conditions: (1) the current working face with fresh admixed sludge/solid waste; (2) an older fill area that had received admixed sludge/solid waste; and (3) an older area that had received only solid waste. For the latter two fill conditions, areas were selected that were filled at about the same time as the three test cells. Each time drilling was conducted, bore holes for the latter two landfill conditions were drilled in the same place to obtain continuous data. Bore holes were drilled to a depth of 20-feet or to the bottom of the fill wherever feasible. The bore hole locations for 1972 are shown in Figure VIII-2. Samples were taken at two-foot depth intervals. The drilling equipment, sampling methodology, sample analyses and coring observations were done as described in Section VII. B. 5. and Appendix A. Prior to backfilling the bore holes with the waste material removed, 10-foot long 0.25-inch I.D. polyethylene gas sample probes were placed into the holes as shown in Photograph VIII-2 c.

5. Vector Studies. Special studies of fly emergence were begun in August 1972. Dr. John H. Poorbaugh, Jr., Ph. D., Vector Control Specialist of the State of California Department of Public Health, Bureau of Vector Control and Solid Waste Management assisted in providing guidelines by which to conduct the fly emergence studies. Mr. Harvey I. Magy, Southern California Region, of the same State Department, also assisted in the fly test program and provided 14 modified eye-gnat emergence traps

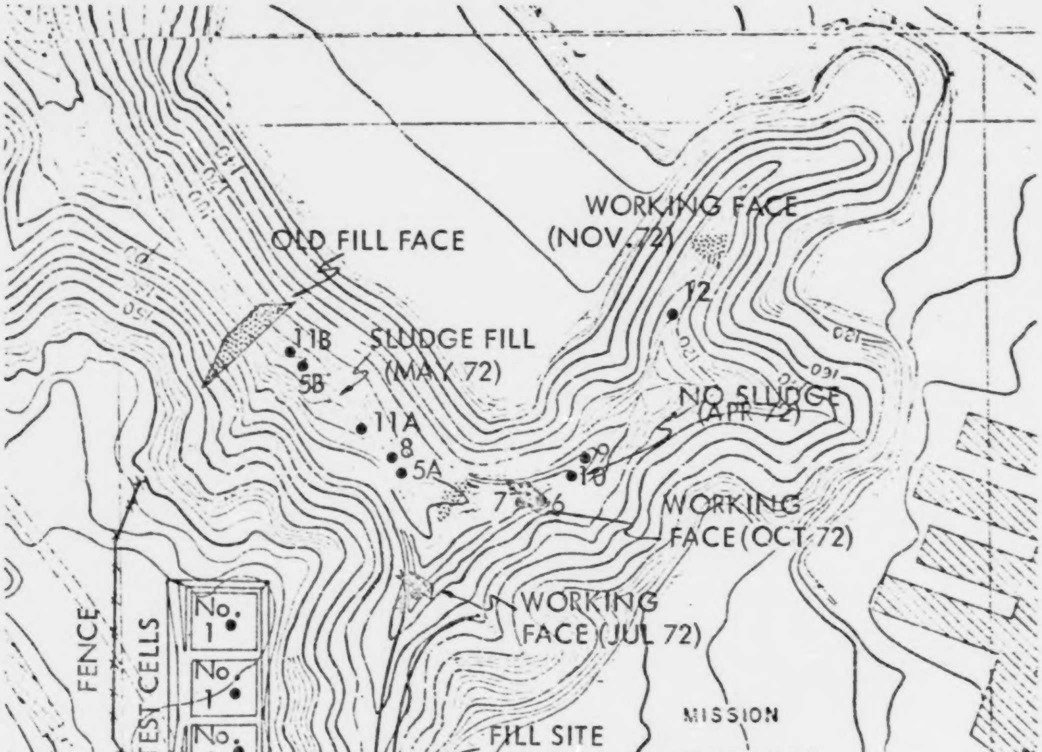

EQUIPMENT YARD
SLUDGE APPLICATION
SOLID WASTE SAMPLE
(3 TRUCK LOADS)

PLAN


12 ft LIFT
1
2
2' THICK WASTE

APPLY THE SEWAGE SLUDGE ACROSS THE TOP OF THE WASTE SURFACE. WORK THE WASTE UNTIL IT IS 2 FT THICK ON THE SLOPE AS SHOWN.

FIGURE VIII-1
SOLID WASTE AND
SLUDGE PLACEMENT


OLD FILL FACE
WORKING FACE (NOV. 72)
12
11B
5B
SLUDGE FILL (MAY 72)
11A
8
5A
NO SLUDGE (APR 72)
9
10
7
6
WORKING FACE (OCT 72)
WORKING FACE (JUL 72)
FENCE
TEST CELLS
No. 1
No. 1
No. 1
FILL SITE ACCESS ROAD
MISSION ELEMENTARY SCHOOL
GLOUCHESTER
LANDFILL GATE OPERATOR
CAPE
LANDFILL ACCESS
AVE
MISSION
BORE TEST HOLES
UTILITY SHED AND TOILET
WATER VALVE
FILL FACE
N
SCALE 1" = 400'

CITY OF OCEANSIDE/E.P.A.

FIGURE VIII-2
LANDFILL SITE
BORING LOCATIONS
1972

a. CORED SLUDGE/WASTE ADMIXED FILL MATERIAL.

b. CORED SOLID WASTE FILL MATERIAL (NO SLUDGE).

c. PLACING GAS PROBE IN BORE HOLE.

CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VIII-2

CORE MATERIALS AND GAS PROBE

to conduct the study. Mr. Daniel Bergman, Vector Ecologist with the San Diego County Department of Public Health assisted in setting up the fly emergence test plots and traps, and helped monitor and identify flies on the first two tests completed in August and September 1972. The routine monthly tests were conducted by Ralph Stone and Company, Inc. and Oceanside Waste Disposal Department personnel thereafter.

To conduct the studies, two separate test plots were prepared each month, approximately 15 feet by 15 feet in area, with a three-foot depth of solid waste. One area received digested liquid sewage sludge, the second area contained only solid waste. A six-to twelve-inch moist cover soil layer was applied and compacted as is done on the regular landfill. Four fly emergence traps, each three feet by three feet wide and one foot high, were placed three to five feet apart on each of the two test plots (eight traps total). A schematic of the fly emergence traps is shown in Figure VIII-3. The emerging flies were attracted to the light in the glass jar in which they were trapped and collected daily, counted and identified by species. Flies entering the jar were prevented from leaving by the screen. A tightly packed two-inch seal of soil was placed along the bottom edges of each trap to prevent light entrance and fly escape. Emergence tests were conducted for two-week periods to cover the maximum possible time for egg hatching, larvae stages and emergence as adult flies.

C. Results and Discussion

1. Initial Trial Run at the Old Landfill. The following are highlights of the results of the initial trial run at the old landfill:

a. It was impractical to drive a heavy rubber-tired tank truck over newly deposited solid wastes to distribute sewage sludge. The truck had difficulty traversing the waste and broke a rear axle on its third pass. It was towed through the waste thereafter by the CAT 977 K until it unloaded the 1,250 gallons of sludge. A total of two passes was made in each of three paths across the waste.

b. It was observed that approximately 50 sea gulls were feeding on the exposed solid waste prior to applying the sludge. After application none of the sea gulls would feed on or traverse the wastes coated with digested sewage sludge. Some sparrows approached the sludge but did not appear to feed in the sludge admixture.

c. The earthy odor of well-digested sewage sludge was observed during sludge disposal and for approximately 30 minutes thereafter within 30 feet of the area. When the liquid soaked into the solid waste and the sludge surface dried, the odor was reduced until it was noticeable only when standing next to the waste. The normal solid waste landfill pig-pen odor was apparently masked by the earthy odor of the digested sludge.

d. The test area was subsequently worked into the face of the regular landfill by pushing and working up the slope of the fill face.

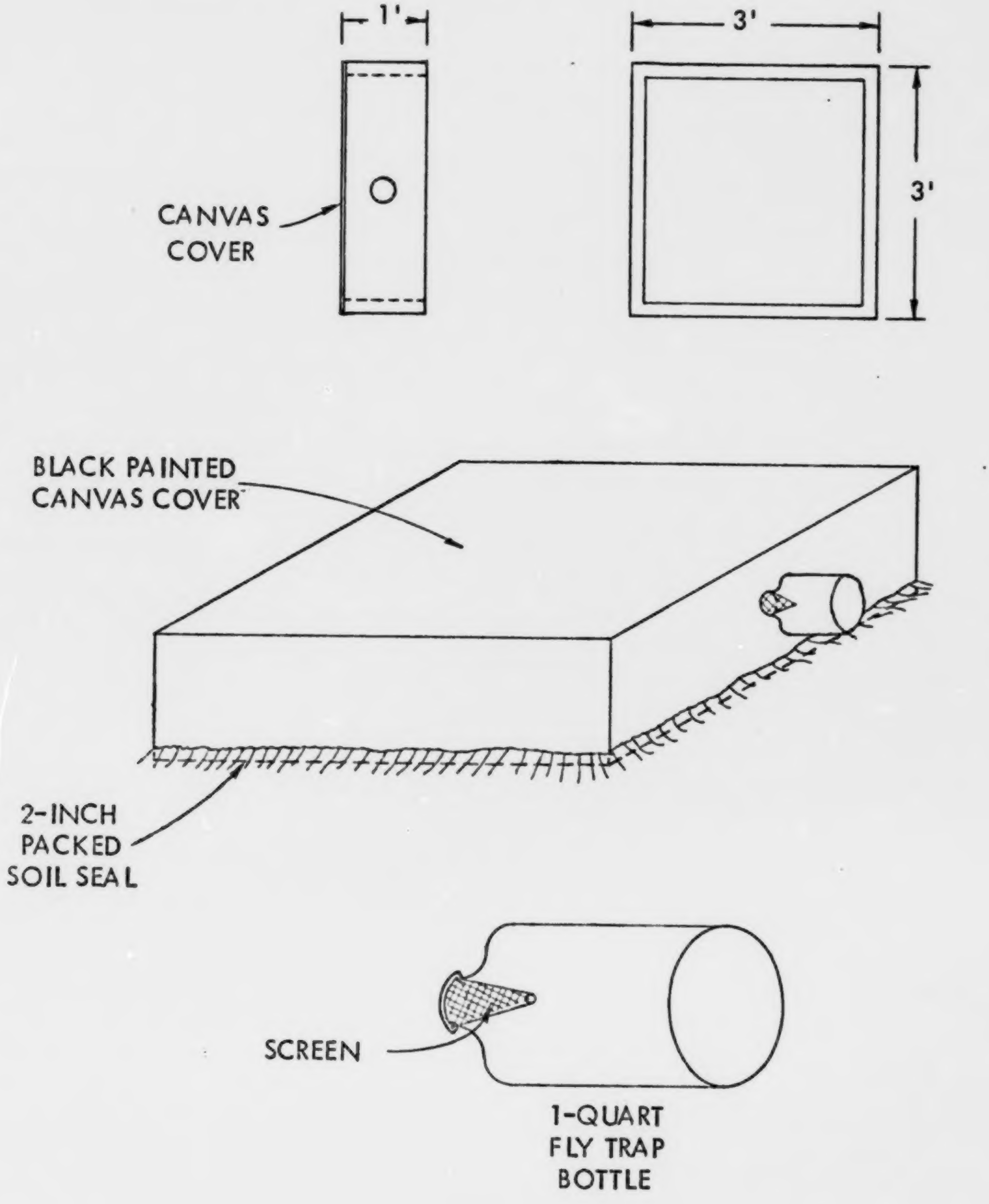

1'
3'
3'
CANVAS COVER
BLACK PAINTED CANVAS COVER
2-INCH PACKED SOIL SEAL
SCREEN
1-QUART FLY TRAP BOTTLE

FIGURE VIII-3

SCHEMATIC OF FLY EMERGENCE TRAPS

e. When the test waste/sludge mixture was removed from the test area it was observed that about 70 percent of the surface area was dry. Very little sludge bypass drainage or run-through had occurred.

2. "Extended" Field Tests. The results of the extended demonstration tests are presented below in summary form.

a. Equipment Operation. The CAT 977 K Dozer landfill equipment operator reported it appeared easier to work the solid waste/liquid sludge mixture than regular waste. It compacted better and gave off less dust. Some slippage of the dozer tracks occurred occasionally when working on the slope face in areas where sludge pools had formed.

b. Sludge Disposal. It was difficult to achieve uniform liquid sludge spreading from the single 4-in. gravity-feed tank truck discharge pipe. The concentrated high velocity flow discharge tended to channelize the solid waste,and the sludge bypassed along to the bottom of the new lift-old lift interface,creating minor runoff. A new splash plate assembly was ordered for the large 3,500 gallon tank truck,but it did not arrive until full-scale sludge disposal was under way. At times as much as 50 or 60 gallons of sludge bypass runoff was observed from one 3,500 gallon tank truck sludge load. The runoff was contained by earthen dikes along the foot of the new fill face. (See Photograph VIII-3 a.)

In order to prevent runoff, solid waste dikes were formed on the sloped base of the working face of the fill. The dikes proved effective if the sludge was worked into the solid waste by the tractor dozer to achieve suitable admixture and compaction. Additional solid waste was admixed into the sludge pools behind the dikes. It was found difficult to work the solid waste immediately with pooled sludge due to poor dozer traction. After the liquid sludge soaked into the solid waste for about one hour, however, it was easily worked.

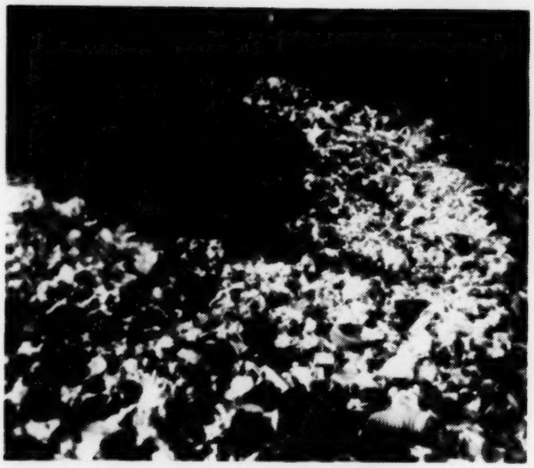
After spreading the liquid sludge, steam was observed in an uncovered area one to two feet below the landfill surface. Routine observations were made once a week for 33 days during the seven month preliminary field demonstrations. The landfill operator's observations are tabulated in Appendix E and summarized below.

c. Odor. Earthy sewage sludge odors were noted 5 days (17 percent); normal landfill odors, 13 days (43 percent); and no odors, 12 days (40 percent) of the time.

d. Blowing Litter. Windy days in Oceanside are rare. Blowing litter was reported during only one day (3 percent of the observed period) in the landfill site. It occurred during a day when a moderate wind was blowing. The sludge which covered the surface of the test area apparently held the waste down. Water truck irrigation was used to restrain litter from blowing in the regular landfill area. It appears that the sludge can provide an effective control for blowing litter in the working landfill face, but not for the truck roadway and dumping access areas.

a. GRAVITY SLUDGE DISCHARGE.

b. GRAVITY SLUDGE DISCHARGE THROUGH A FLEXIBLE HOSE.



c. SOLID WASTE DIKES FOR SLUDGE CONTAINMENT.

PHOTOGRAPH VIII-3

FIELD DEMONSTRATION
SLUDGE DISPOSAL IN THE LANDFILL
SLUDGE APPLICATION METHODOLOGIES

e. Animals and Flies. Sea gulls were the most abundant animals observed foraging in the solid waste. They were observed in the sludge test area on five occasions, but only on wastes that were not coated with sludge. A few small birds were noted in the sludged area on two days and lizards on one day. Flies were always present in the sludged-solid waste admixtures.

f. Sludge Spreading. Poor spreading and solid waste admixing were noted on two days (6 percent) and some sludge runoff occurred on six days (18 percent of the observations over the seven-month period).

3. Full-Scale Demonstration at the New Landfill. The major problems encountered in the full-scale demonstration wherein all of the city's liquid digested sludge was disposed into the available solid waste were those of sludge admixture and operator acceptance. The field observation data is included in Appendix F and summarized below.

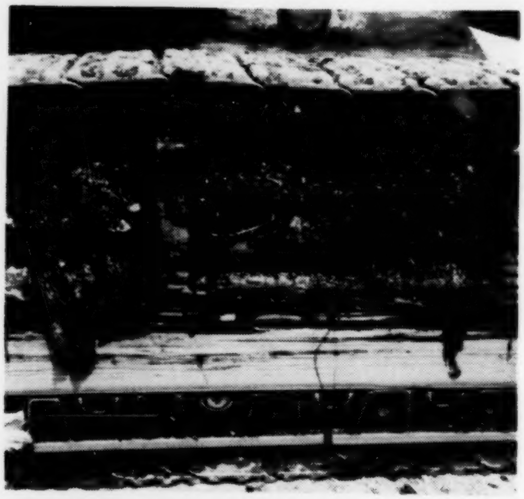
a. Sludge Runoff. Initially when the sludge was hauled and spread on a two-days per week basis, some appreciable runoff occurred. Significantly smaller quantities of runoff, however, resulted when better admixture was provided by a 5-days per week sludge spreading schedule. The use of solid waste diking to prevent sludge runoff was tested. The effort, however, did not prove completely satisfactory since it was difficult to work the pooled sludge-solid waste mixture until most of the liquid had been absorbed by the solid waste. When the runoff volume was large (50 to 100 gallons) an earth dike was maintained below the foot of the new fill face slope to contain runoff and allow it to be absorbed into the older lift. (See Photographs VIII-3c, and VIII-4 a, b, and c.)

A third approach to the problem of runoff control which was investigated in June 1972 was that of reducing the slope of the fill working face. It appeared, however, very difficult to get adequate spreading of the sludge onto a flat surface with gravity discharge unless the truck is actually driven over the fill surface. This is not practical with normal truck equipment and, hence, provides an added cost. A modification of the flat-spreading approach which was also tested (and found undesirable) consisted of digging trenches through the soil cover on top of the completed fill lift. The sludge was discharged into these trenches, and the trenches were subsequently ripped through to allow for sludge spreading. This procedure, however, resulted in a severe odor nuisance and complaints were received from a school 300 feet away. Direct liquid sludge spreading on the flat surface of a completed fill using small berms worked well with a 3- to 6-in. depth sludge application drying in a day or less. (See Photograph VIII-5.) Pumping was found to be a superior way of spreading sludge on flat or other surfaces. It was used for the test cells, but it costs more than gravity feed.

a. LANDFILL FACE SLUDGE SPREADING FLOW PATTERN.

b. SLUDGE RUNOFF.

c. FLIES AND FLY MAGGOTS ENTRAPPED IN SLUDGE RUNOFF.

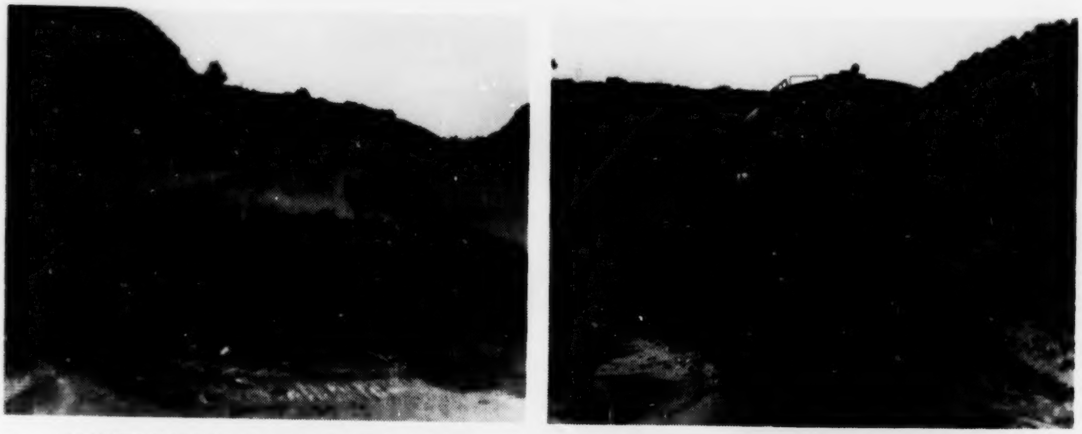


d. SLUDGE/SOLID WASTE ACCUMULATION IN DOZER TRACK DRIVE.

CITY OF OCEANSIDE/E.P.A.

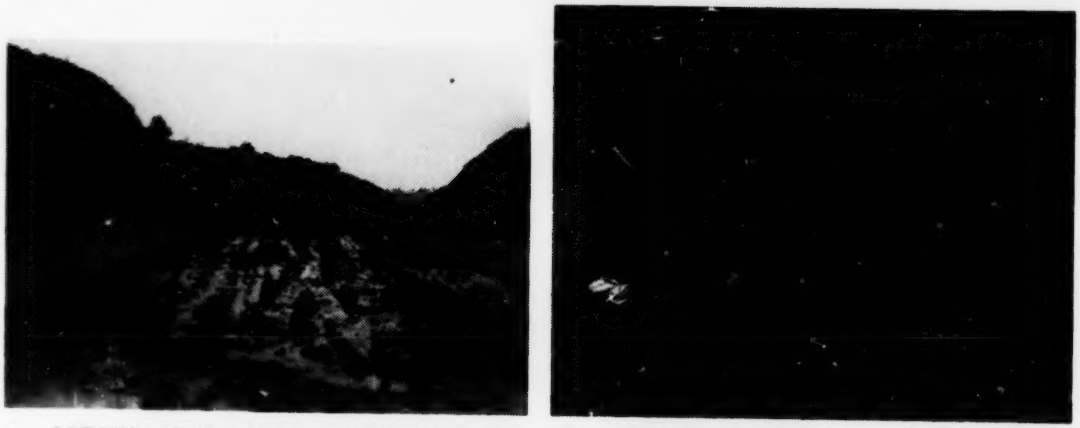
PHOTOGRAPH VIII-4

SLUDGE DISPOSAL
FIELD OBSERVATIONS



a. DOZER RIPPING LANDFILL LIFT COVER SOIL PRIOR TO SLUDGE APPLICATION.

b. SLUDGE APPLIED TO COVER SOIL OF LANDFILL LIFT.



c. LIQUID SLUDGE ON LANDFILL LIFT COVER SOIL.

d. DRIED SLUDGE ON LANDFILL LIFT COVER SOIL.

CITY OF OCEANSIDE/E.P.A.

PHOTOGRAPH VIII-5

SPECIAL TESTS OF SLUDGE
ADMIXTURE INTO FILL COVER
SOIL FOR DRYING

During July and August of 1972, an eight-foot truck boom suspending a four-inch diameter eight-foot long flexible hose was used to spread sludge by gravity feed. Although the spreading was improved over single nozzle discharge, handling the hose was found to be troublesome due to sludge spillage. Also, sludge odor emanated from the hose after disposal. During 10 days of observation in July 1972, runoff occurred on seven days in quantities of 20 gallons or less.

In September 1972 and thereafter, a double splash-plate assembly was used for gravity spreading of sludge. The double splash-plate distributed sludge over an estimated area about 12 feet wide and six feet deep. The double splash-plate assembly was superior in spreading sludge more uniformly over the surface of the working face of the solid waste fill. The truck had to be moved a minimum of three times across the top of the working face to avoid channeling and resultant runoff when using the double splash-plates.

Prior to September 1972, when cover soil was not placed on the working face at the end of each day the sludge truck began disposal at about 6 A.M. With the initiation of daily cover soil placement on the working face in September 1972, there was no longer any exposed solid waste to admix with the sludge until the first load of solid waste was disposed. This resulted in a change in the sludge disposal schedule. During operation without daily soil cover no external environmental problems with odor or public health were encountered, although a large fly population was observed.

Initially, the sludge disposal truck operated from 5:30 A.M. to about 1 P.M. It was found that all of the sludge was disposed onto one-third to one-half the daily solid waste quantities. Daily solid waste disposal began primarily after 10 A.M. and continued up to 7 P.M. On the revised sludge disposal schedule, sludge was taken to the landfill after 10 A.M. after the first several loads of solid waste were disposed. A reduction in sludge runoff was noted in that runoff quantities generally never exceeded 50 gallons.

Other steps taken to minimize sludge runoff, control vectors and conserve cover soil included the following: (1) providing better solid waste compaction and (2) reducing the width of the landfill working face by up to one-third. The working face was normally 150 to 200 feet wide on a side; this was reduced to about a 30-foot width, 70 to 80 foot length and 12 to 15-foot lift. The resultant proportionally thicker and denser solid waste layers provided additional absorptive capacity and better dozer footing conditions. Sludge runoff has been negligible with the smaller working face. Four tank-truck loads of sludge (14,000 gallons) can be readily disposed daily without significant runoff if scheduled for unloading in proportion (about 0.6 lb sludge per lb solid waste) to solid waste deliveries. The few gallons of sludge runoff at the toe of the working face, if present, are easily covered with refuse or dirt as part of the normal sanitary landfill activity. Since the working face is on a prior lift, for runoff into ground or surface water to occur, liquid must pass through the absorbent solid waste in lower lifts. A working face slope of from 25 to 30 percent was considered best for minimizing runoff and providing suitable dozer traction.

b. Sludge Disposal During Rainfall. On November 7, 1972, 0.21 inches of rain fell at the Oceanside landfill. Sludge was deposited on the uncovered face of solid waste which had been thoroughly wetted by the rainfall. Within a couple of minutes after sludge unloading began (800 gallons unloaded), some sludge runoff was observed at the toe of the working face. Sludge unloading was suspended and the truck moved to a newly started working face to unload the remaining 2700 gallons. No runoff occurred from the new working face.

On December 4, 1972, 0.36 inches of rain fell. The landfill was inspected for runoff. It was observed that rainfall drainage from two storm drain pipes, one from the adjacent elementary school and another from the adjacent junior high school track field, flowed uncontrolled over the landfill access roads and onto the fill working face. It is not uncommon to have a "design" storm in the semi-arid Oceanside area which floods out the normally dry San Luis Rey River. The point of this discussion is that even though the Oceanside annual rainfall is relatively low (12 in./year), the individual storm intensity periods may be excessive and, hence, a very fair test of the sludge absorption problems during wet weather was obtained. Corrective action was subsequently taken by grading to re-route the runoff along earthen channels paralleling the endge of the canyon and away from the landfill. Three loads of sludge were disposed on December 4. Some runoff was observed along the toe of the working face toward the end of the third unloading operation. The runoff consisted of a diluted mixture of sludge and rain water.

Obviously, if the solid waste fill is saturated with enough rainfall the liquid sludge runs off more easily. Since runoff didn't occur on December 4, 1972 until the third load of sludge, it appears that the solid waste must be saturated to near its moisture absorption capacity before runoff results.

A number of solid waste disposal trucks became stuck in the unexpected heavy rain, and mud on the landfill unloading area during the rain, but no problems occurred with the sludge truck.

c. Odors. Daily surveillance for odor during the period from May 1 through July 31, 1972 indicated the in-situ presence of normal refuse odors for 36 percent of the time and the presence of earthy digested sludge odor for 19 percent of the time. No specific odors were identified during the remaining 45 percent of the observations (see Appendix F for data). During a warm period in the last week of October, 1972, the landfill working face was in a position about 80 feet directly below the adjacent Mission Elementary School cafeteria (see Figure VIII-2). A complaint was received by the Oceanside Public Works Director from the school authorities that a "musty odor of old unwashed dirty clothes" pervaded the cafeteria. The landfill working face was promptly moved to another section of the canyon site; no other public complaints have been received before or afterwards. The area below the school cafeteria was filled with solid waste thereafter only when school was not in session. Observations by the Ralph Stone and Company, Inc. Field Engineer verified the existence of a strong "pig pen" type of odor from restaurant garbage, etc. at the landfill when the complaint was received.

d. Operator Problems. During April and May, 1972 (second and third months of the demonstration) the dozer operator continually reported strong noxious odors being emitted from the sludge admixed fill. These reports were investigated by the Consultant's field engineer and other staff personnel who conducted qualitative and quantitative tests. Hydrogen sulfide field tests were made, and gas samples were collected for analysis by gas chromatography. The field tests and gas chromatographic analysis for hydrogen sulfide proved negative. It is possible that the odors noted by the dozer operator may have been from a load(s) of partially digested sludge which had been inadvertently disposed. Also, the operator routinely ate his lunch directly in the fill face area and he was advised to eat away from the fill. The dozer operator was examined by medical doctors and found to be healthy. The operator was offered the opportunity to transfer his work and be a truck driver in the refuse collection system. He has elected to continue to operate the dozer tractor full time on the demonstration landfill. The experience with the dozer operator illustrates a key factor in liquid sludge disposal into a sanitary landfill. Special training and further incentives are required to obtain employee acceptance of any new work activity.

e. Blowing of Litter. Small amounts of blowing litter were reported at the landfill on three days (7 percent of the observations made from May 1 to July 31, 1972). Water was applied to the fill working face and over unloaded solid waste primarily when sludge was not being spread. Water application during full scale sludge disposal in 1972 averaged 8,318 gallons per week (34.7 tons per week), or 1,540 gallons per day (6.4 tons per day based on 5.4 days per week). Water application in 1971 prior to sludge disposal into the landfill averaged 22,360 gallons per week, which indicated a 63 percent reduction in the amount of water used in conjunction with full-scale sludge disposal. Water application rates showed no relationship to weather. Sludge was deemed unacceptable for controlling litter and dust on the access road and solid waste unloading areas. Thus, some use of water is necessary on these latter areas, especially toward the end of the working day after the daily sludge quantity is disposed.

f. Observations of Birds and Animals. Sea gulls were the most common animal life observed at the landfill, being sighted on 16 observation days (36 percent); up to 100 gulls were observed on two occasions. Pigeons, blackbirds, sparrows, rabbits, rats and squirrels were also occasionally sighted; up to 30 pigeons and a like number of crows were observed on separate days. The birds and other animal life initially avoided foraging on solid waste areas covered with wet sewage sludge. It was observed after about seven months of full-scale sludge disposal (about mid-September 1972) that sea gulls and other birds had adapted and were foraging in the wet sludge/waste admixture after the dozer had worked the waste. While foraging, the birds appeared to avoid the particles of waste that were completely covered with wet sludge. After working the refuse, the dozer exposed underlying solid waste that was not covered with wet sludge, thus providing the birds with unoffensive foraging areas. On one occasion, four sea gulls were observed walking in pooled sludge. The sea gulls by December 1972 had overcome their initial aversion to foraging in the wet sewage sludge.

g. Fly Studies. Flies are not usually associated with digested wet sewage sludge per se, but it was observed that they will forage in solid waste wetted with sludge. See Photograph VIII-4 c which illustrates flies and maggots entrapped in sludge runoff. Observations indicate that houseflies and their larvae don't prefer sludge, but they forage in it and thereby are exposed. Counts of the density of flies in the sludge/solid waste fill indicated densities of five to ten flies per square foot. Since the entire landfill was used for sludge disposal, data on solid waste fill was not obtained.

Special inquiries indicate that no increase in flies were observed or reported from the adjacent school or residential housing projects. No migration of flies was observed, but further fly studies are planned. It is known that houseflies are attracted by the odors of food, and in this case the landfill appeared to maintain their attention. Blowflies and houseflies are reportedly wide-ranging (1/2 to 6 miles) and, therefore, the potential for migration may exist if there is a lack of suitable food items at the landfill. Daily compacted earth cover is needed to maintain sanitary landfill conditions.

Fly emergence studies conducted in test plots with and without sludge admixture were initiated in August 1972. After the initial 14-day test it was observed that dirt seals around the base of three traps were destroyed. Flies collected from the jar traps during the study were identified by State of California Department of Public Health Vector Ecologists to be:

Cochliomyia macellaria, three specimens; Phaenicia sericata, five specimens; Phaenicia cuprino, 10 specimens; Ophyra leucostoma, two specimens; and Sepsidae, one specimen.

These species were different from the flies found in the test drums (see Section VI). No large domestic houseflies were found in the test drums, only varieties of small flies the size of gnats.

On the first test, a substantial number of flies emerged through the partially compacted soil covers from both test plots, with and without sludge, into the traps. This large emergence was not anticipated, and no provision was made to kill flies when they entered the collection jars, nor were they collected daily. It was suspected that ants may have removed flies that died in the collection jars, and that flies escaped through the disturbed dirt seals. As a result of the above, no quantitative comparisons should be made between the two test plots.

In theory, a six-inch layer of well-compacted soil will prevent fly emergence from solid waste fill irrespective of the composition of the waste fill (in this case admixture with wet sewage sludge). The efficacy of the cover, however, may vary with local soil type, compaction technique and soil moisture content.[29]

Based on the results of the initial study, subsequent fly emergence tests were designed to determine the following:

1) Soil cover compaction effects on fly emergence.

2) The adequacy of the type of cover soil available at the site (coarse to fine sand to provide a barrier to fly emergence).

3) The effect of climatic conditions.

4) The influence of sewage sludge admixed with solid waste on fly propogation and emergence.

The initial test verified that the one square meter modified eye-gnat traps were suitable to study emergence of muscoid flies from landfill cover soil.

Additional fly emergence tests conducted in November and December 1972 with eight to twelve inches of cover soil resulted in no fly emergence. It was observed that fly larvae were in the solid waste disposed during these tests, although the fly population at the landfill was several orders of magnitude less than during the August-September 1972 tests (the peak fly season). The lack of emergence was attributed to a combination of better compacted soil cover, and a more hostile (cooler) landfill environment that was less conducive to propagation of fly larvae and adults.

h. Landfill Accidents. A summary of observed accidents and injuries incurred by Waste Disposal Department personnel and others at the Oceanside landfill is given in Table VIII-2. It is apparent from the nature and causes of injuries that none were attributable to the disposal of sewage sludge.

i. Disinfection.[1] Sewage sludge can be disinfected by storage as well as by various physical, chemical and biological processes. Heating, chemical addition, and drying of raw sludge can also provide disinfection. Pathogenic organisms include bacteria, viruses, protozoa, worms, and other microorganisms. (The following paragraph is quoted from Reference 1.)

"A study of the survival of E. coli in digested primary sludge showed that they survived for 7 weeks at 37 C and for 2 weeks at 22 C. The coliform organisms apparently disappeared because of competition from other microorganisms better adapted to the digestion environment.[30] Disease organisms such as typhoid-dysentery bacilli, polio virus, anthrax, ova of parasitic worms, and brucella have been thought to have a rapid mortality rate due to their sensitivity to the unacceptable digestion environment. One study where raw and digested sludge was exposed to 55 C for two hours resulted in 100 percent destruction or inactivation of Ascaris lumbricoides ova.[31] Keller reported that thermophilic digestion destroyed all ova of parasitic worms and cysts of amoebae parasitic to man in 24 hours.[32]"

Studies completed to determine pathogenic bacteria counts present in solid waste without sewage sludge have indicated that bacteria populations vary widely between samples. Total viable coliform densities ranged from $3.4\ (10)^5$ to $5.1\ (10)^7$ organisms per gram of solid waste, and fecal coliform in the same samples ranged from $1.5\ (10)^4$ to $8.1\ (10)^6$ organisms per gram in samples from eight solid waste disposal systems studied by Environmental Protection Agency personnel. The presence of fecal coliform groups in large numbers indicates extensive normal contamination of solid waste by fecal matter of either human or animal origin.[33]

TABLE VIII-2
LANDFILL OPERATING PERSONNEL INJURIES

Date	Nature of injury	Cause of injury
1969		
Oct	Sprain right arm and shoulder.	Stepped on end of can in a trash pile and other end of can tripped him.
1970		
Aug	Twisted right ankle.	Stepped on ridge at landfill and twisted ankle.
Oct	Stepped on nail (left foot).	Guiding truck back to dump and stepped on nail.
Oct	Injured right knee.	After washing dozer he started to climb on, slipped on step hitting knee on tracks.
Oct	Sprained ankle.	Sprained ankle getting off dozer.
1971		
Jan	Sprained knee.	Sprained knee getting on and off dozer.
Apr	Blow on side of head (right). (sludge disposal initiated).	Hit on side of head with lever of rear truck door when opening it.
Nov	Pulled muscle of left shoulder.	Pulling cables and wires from dozer tracks.
Nov	Twisted right knee.	While doing some plumbing, wrench slipped and he fell on knee, twisting it.
Dec	Injured back of right hand.	Injured hand while closing gate at end of day.
1972		
Apr	Pain in lower abdomen (right).	Hit himself on right lower abdomen with lever of tailgate on dump truck.
May	Mashed little finger (left).	Caught little finger between throttle lever and spring on dozer (he is being trained on dozer).
July	Sprain right thumb.	Opening door of truck, lever hit thumb, injuring it.
Aug	Chest.	Pressure caused door to hit him in chest while opening back door of truck.

TABLE VIII-2 (Cont.)
LANDFILL OPERATING PERSONNEL INJURIES

Date	Nature of injury	Cause of injury
1972		
Aug	Bruised 2 fingers (left hand).	While operating dozer ran over some steel cable and piece of cable hit him on left hand.
Aug	Stepped on nail (right foot).	Cleaning out track and stepped on nail.
Oct	Bruised skin (left leg).	Left his post at gate and climbed on dozer to see operator service it. Slipped off track bruising left leg. (Sludge not noted as cause of slip).

While the existence of pathogenic bacteria in solid waste is generally known, the exposure of landfill personnel to the pathogens has not been quantified. It is not known if pathogenic bacteria or viral densities in Oceanside municipal solid waste are in the range of the high densities noted above. In the absence of quantitative data, an indicator of hazard may be illnesses incurred by landfill operating personnel due to exposure to solid waste-borne pathogens.

No illnesses of landfill personnel have been attributed to the landfill disposal of sewage sludge and solid waste through Year 02. No illnesses were reported in the literature or in the Ralph Stone and Company, Inc. nationwide survey on sludge disposal into landfills.

A supplemental demonstration grant was proposed to conduct investigations to determine if pathogenic enteric virus and bacteria are present and survive in the Oceanside demonstration landfill. EPA indicated a separate study would be planned.

4. Core Sampling. The results of core sampling programs completed on July 26, October 2, and November 29, 1972 are discussed in the following paragraphs. Each core sampling program provided one bore hole each in: freshly placed sludge/solid waste up to 14 days old; sludge/solid waste placed within one month of the test cell completion; and solid waste only placed within one month of test cell completion.

a. Temperature Profiles. The temperature profiles by depth from the cover soil surface are given in Tables VIII-3 through VIII-5. The average temperatures in the freshly placed sludge/solid waste bore hole were significantly higher than the other bore holes during the first two drilling periods. The relatively shallow depth of freshly placed fill on the November 29 drilling is thought to have resulted in the lower average temperature. Steam was observed escaping from the bore holes in freshly placed fill during the first two drillings. Average temperatures in the older fill without sludge (Table VIII-5) were higher than in older fill with sludge (Table VIII-4). One explanation for this may be that the higher moisture (see Tables VIII-9 through VIII-11) in the fill with sludge tended to keep temperatures lower. In Table VIII-5, during the November 1972 drilling, the first 12 feet of fill was newly filled with sludge; the 12-to 20-foot depths were old fill without sludge. The old fill had a higher average temperature than the newer fill above. Under each waste-fill condition, it is evident from Tables VIII-3 through VIII-5 that ambient temperatures had influenced the fill temperatures down to a depth of four to six feet. Even so, the average temperature in the two bore holes in the older fill did not decrease with ambient temperature. This indicates the effect of temperatures of the solid waste when placed on subsequent landfill temperatures.

b. Organic Content. The organic contents by depth are given in Tables VIII-6 through VIII-8. The average organic content in the freshly placed sludge/waste bore hole fill was generally greater than for the two older fill bore holes. No trends were evident over time or by depth in the fill material.

TABLE VIII-3

LANDFILL BORE HOLE TEMPERATURE PROFILE - FRESH SLUDGE/ WASTE FILL (0 - 2 WEEKS OLD)

	Depth, ft below soil surface	Temperature, deg F Days since landfilling completed * Jul 72 0-7	 Oct 72 0-7	 Nov 72 14
Ambient air		81	77	80
Soil	0 2	89	86	68
Solid waste/ sludge	4	103	88	68
	6	116	104	72
	8	122	109	77
	10	104	108	80
	12	119	114	79
	14	124	112	BOF #
	16	109	115	
	18	118	113	
	20	116	109	
	22	116	111	
	25		109	
Average$^+$		115	108	75

* Approximate number of days.
+ Average for solid waste/sludge.
# BOF = bottom of fill.

TABLE VIII-4
LANDFILL BORE HOLE TEMPERATURE PROFILE - SLUDGE/WASTE
FILLED MARCH 1972

	Depth, ft below soil surface	Temperature, deg F Days since landfilling completed * Jul 72 140	 Oct 72 208	 Nov 72 276
Ambient air		77	72	66
Soil	0 2	88	71	59
Solid waste/ sludge	4	92	86	62
	6	89	84	69
	8	78	88	81
	10	82	87	86
	12	71	86	89
	14	74	88	92 BOF #
	16	74	81	
	18	75 BOF #	79	
	20		73	
Average +		79	82	79

* Approximate number of days.

+ Average for solid waste/sludge.

# BOF = bottom of fill.

TABLE VIII-5
LANDFILL BORE HOLE TEMPERATURE PROFILE-SOLID WASTE FILLED
JANUARY 1972

	Depth, ft below soil surface	Temperature, deg F Days since landfilling completed *			
		Jul 72 195	Oct 72 263		Nov 72 321
Ambient air		78	74		80
Soil	0				
	2	84	2	New sludge/waste	71
Solid waste	4	89	86		76
	6	90	82		87
	8	96	86		88
	10	95	80 BOF #		87
	12	77			91
	14	106 BOF #			83
	16				
	18				92
	20				94 Refusal
Average +		92	83		85/90 **

* Approximate number of days.
+ Average for solid waste/sludge.
# BOF = bottom of fill.
** Sludge waste temp/waste only temp.

TABLE VIII-6
LANDFILL BORE HOLE ORGANIC CONTENT - FRESH SLUDGE/WASTE FILL (0-2 WEEKS OLD)

	Sample depth, ft below soil surface	Organic content, percent dry wt Days since landfilling completed * Jul 72 0-7	 Oct 72 0-7	 Nov 72 14
Soil	0 2	2.0	2.0	5.9
Solid waste/ sludge	4	29.4	63.0	50.7
	6	36.3	56.1	56.2
	8	50.0	59.7	32.5
	10	45.6	21.5	33.8
	12	16.2	50.3	40.9
	14	26.2	63.4	7.4 ** BOF #
	16	34.7	18.4	
	18	28.9	55.8	
	20	26.5	60.0	
	22	26.9	31.7	
	25		27.0	
Average +		32.1	46.0	36.9

* Approximate number of days.
+ Average for solid waste/sludge.
# BOF = bottom of fill.
** Bottom soil under fill.

TABLE VIII-7
LANDFILL BORE HOLE ORGANIC CONTENT - SLUDGE/WASTE FILLED MARCH 1972

	Sample depth, ft below soil surface	Organic content, percent dry wt Days since landfilling completed [*] 140	208	276
Soil	0	3.2	3.2	2.4
	2			
Solid waste/ sludge	4	30.5	6.9	44.2
	6	23.8	19.2	13.8
	8	25.0	19.4	50.3
	10	27.0	30.4	48.0
	12	25.3	30.1	55.7
	14	18.3	45.6	13.3 BOF [#]
	16	29.3	36.8	
	18	38.2 BOF [#]	8.0	
	20		6.1 [++]	
Average [+]		27.2	22.5	37.6

[*] Approximate number of days.
[+] Average for solid waste/sludge.
[#] BOF = bottom of fill.
[++] Bottom soil under fill.

TABLE VIII-8
LANDFILL BORE HOLE ORGANIC CONTENT - SOLID WASTE FILLED JANUARY 1972

	Sample depth, ft below soil surface	Organic content, percent dry wt Days since landfilling completed *			
		195	263		321
	0				
Soil	2	1.9	1.9		3.7
Solid waste/ sludge	4	43.2	45.6	Sludge/waste	58.8
	6	42.6	33.7		56.7
	8	36.2	20.7		79.6
	10	39.9	7.3		29.7
	12	31.5	7.3 ++		19.1
	14	30.7	BOF #		8.7 **
	16	31.1			40.4
	18	BOF #			42.5
	20				Refusal
Average +		36.4	22.9		56.2/27.7

* Approximate number of days.

+ Average for solid waste/sludge.

# BOF = bottom of fill.

** Soil-intermediate left cover soil.

++ Bottom soil under fill.

The organic content of the cover soil increased significantly on two holes and decreased significantly on one hole in November. This occurred after 2.63 inches of rainfall fell one week prior to the November 29 borings. The decrease in organic content in the old sludge/waste fill (Table VIII-7) was contrary to the increases found in the three test cell and two landfill bore holes. Apparently few organics were in this cover soil, or they were washed out or diluted by the rainfall.

Soil samples from the landfill bottom and an intermediate lift (see Tables VIII-6 to VIII-8) indicate organic contents significantly greater than found in the respective cover soils. Also, bottom soil organic content (Table VIII-8, day 263 at the 12 foot depth) showed this same characteristic. This could have resulted from leaching of organic materials from the overlaying sludge/waste fill, or sludge runoff during landfilling.

c. Moisture Content. Moisture contents in the core samples are given in Tables VIII-9 through VIII-11. The average moisture content in each bore hole increased significantly on the November post-rain sampling over the October sampling; the November average moisture contents were the highest of the three drilling periods. No consistent trend in moisture content by depth was evident.

Moisture contents in the cover soils increased as a result of rainfall in the week prior to sampling in November. Moisture contents in bottom soil under solid waste only (Table VIII-11, at 263 days since filling), and intermediate lift soil under sludge/waste fill (Table VIII-11, at 321 days) were both well below moisture saturation levels for fine sandy soils of 42.3 percent dry weight (Table IV-2). Bottom soil in fresh sludge/waste had a moisture content of 28.4 percent, which indicates that some moisture had entered. Since this occurred after the November rainfall, and the average moisture content for the bore hole was higher than during previous sampling in fresh sludge/waste, it appears that rain water infiltration occurred. Since the bottom soil was not saturated in any of the above cases, it also appears that no significant leachate has resulted at these bore holes.

d. Moisture Absorption. Moisture absorption capacities remaining in core samples having the highest and lowest in-situ moisture content, and representative of the range of organic contents, are given in Table VIII-12. The data in Table VIII-12 are given in percent dry weight which is convertible to pounds of water per pound of solid waste by dividing by 100. The additional absorption capacity remaining in the July samples was greater than the other two sample sets. The data appear to be random in that additional moisture absorption was not apparently influenced by in-situ moisture contents, type of fill material, or depth of the sample.

The additional moisture absorbed varied from a low of 0.104 lb water per 1 lb of solid waste (dry wt) to a high of 1.45 lb per lb. The low value falls below the laboratory predicted range of 0.6 to 1.8 lb per lb (dry weight).

TABLE VIII-9
LANDFILL BORE HOLE MOISTURE CONTENT - FRESH SLUDGE/WASTE FILL (0-2 WEEKS OLD)

	Sample depth, ft below soil surface	Moisture content, percent dry wt Days since landfilling completed * Jul 72 0-7	Oct 72 0-7	Nov 72 14	
	0				
Soil	2	6.1	6.1	14.5	
Solid waste/ sludge	4	36.4	9.9	46.7	
	6	26.9	55.6	52.7	
	8	20.3	48.6	68.1	
	10	14.3	25.8	52.1	
	12	25.3	47.3	35.0	
	14	59.2	33.3	28.4 **	
	16	55.7	32.6	BOF #	
	18	70.6	39.1		
	20	65.5	27.0		
	22	63.1	24.5		
	25		22.2		
Average +		43.7	33.3	47.2	Avg. = 41.4

* Approximate number of days.

+ Average for solid waste/sludge.

# BOF = bottom of fill.

** Bottom soil under fill.

TABLE VIII-10
LANDFILL BORE HOLE MOISTURE CONTENT - SLUDGE/WASTE
FILLED MARCH 1972

	Sample depth, ft below soil surface	Moisture content, percent dry wt Days since landfilling completed * 140	208	276	
	0				
Soil	2	7.1	7.1	15.3	
Solid waste/ sludge	4	36.8	13.9	90.4	
	6	67.2	16.8	25.9	
	8	67.9	16.1	75.3	
	10	55.5	28.4	62.2	
	12	93.6	19.9	59.4	
	14	59.9	34.8	98.8	
	16	56.3	37.5	BOF #	
	18	25.1	22.4		
	20	BOF #	14.5		
Average +		57.8	22.7	68.7	Avg. = 50

* Approximate number of days.

+ Average for solid waste/sludge.

# BOF = bottom of fill.

TABLE VIII-11
LANDFILL BORE HOLE MOISTURE CONTENT - SOLID WASTE FILLED JANUARY 1972

	Sample depth, ft below soil surface	Moisture content, percent dry wt Days since landfilling completed * 195	263		321	
	0					
Soil	2	6.2	6.2	SLUDGE/WASTE	7.8	
Solid waste	4	42.0	24.1		43.0	
	6	19.4	30.4		35.1	
	8	23.3	24.8		54.1	
	10	36.0	13.2		22.8	
	12	15.3	6.5++ BOF #		7.6	
	14	21.3			31.7	
	16	21.2 BOF #			17.7	
	18				28.4 Refusal	
	20					
Average +		25.5	19.8		38.8/21.4	Avg. = 22

* Approximate number of days.

+ Average for solid waste/sludge.

# BOF = bottom of fill.

** Soil-intermediate lift cover soil.

++ Bottom soil under fill.

TABLE VIII-12
MOISTURE ABSORPTION CAPACITY OF SELECTED CORE SAMPLES

	Moisture content, percent dry wt Days since landfilling completed/depth, ft										
Fresh sludge/waste	0-7					0-7			14		
	4	8	14	16	20	4	6	22	6	12	
Sample moisture content	26.9	14.3	55.7	70.6	63.1	9.9	55.6	24.5	68.1	28.4	
Additional moisture absorbed	55.9	71.4	75.1	65.5	90.6	64.3	32.5	15.9	27.3	30.7	
Total moisture at saturation	82.8	85.7	130.8	136.1	123.7	74.2	88.1	40.4	95.4	69.1	
Sludge/waste - old fill	140					208			276		
	4	10	12	18		4	10	16	4	12	
Sample moisture content	36.8	55.5	93.6	25.1		13.9	28.4	37.5	25.9	98.8	
Additional moisture absorbed	95.8	60.0	70.7	56.8		30.5	27.1	23.1	10.4	36.7	
Total moisture at saturation	132.6	115.5	164.3	81.9		44.4	56.0	60.6	36.3	135.0	
Solid waste only	195					263			321		
	4	8	12			4	10		6	8	12
Sample moisture content	42.0	23.3	15.3			30.4	6.6		54.1	7.6	31.7
Additional moisture absorbed	136.9	81.4	145.0			20.4	35.3		21.2	29.1	28.9
Total moisture at saturation	178.9	104.7	160.3			50.8	41.8		75.3	36.8	60.6

e. Core Sample Leachate BOD_5. The samples used to determine the moisture absorption capacities in Table VIII-12 were used to generate leachate for the BOD_5 analyses presented in Table VIII-13 The BOD_5 values apparently vary according to the type of organic material and bacteria present, but are not correlated with organic content (see Tables VIII-6 through 8).

f. Odor. Odors were determined during drilling in terms of strength and type at each two-foot sample depth interval. Odors were generally moderate to strong in fresh sludge fill, and weak to moderate in old fill with and without sludge. Odors in both the old fill areas generally became weaker with increasing fill age (on each subsequent sampling).

The most prevalent type of odor detected was classified as sour, the second most common was sweet and the third major odor was of normal landfill. The landfill odor was predominant in the area without sludge, as might be expected.

g. Appearance. In general, the material in fill with sludge was partially or highly agglomerated and required a screwdriver or other sharp probe to dislodge samples from the auger drill bit. The fill material that did not receive sludge was found to be loose and powdery; waste constituents were easily separated and identified. The agglomeration in bore holes with sludge appeared to result from the sludge which was slightly to moderately moist and tended to form a pasty bond with soil and waste particles. Occasionally, random lumps of moist black sludge were encountered.

h. Color. The color of materials in freshly placed fill was, perhaps dirty, but natural (as-received). The color of textiles, plastic, rubber, leather, wood, metal, glass and ceramics were natural; e.g., unaffected by the landfill environment. Food and paper at times appeared bleached or otherwise altered in color in the fill with sludge. Grass, leaves and tree and shrub prunings were often bleached or more intense in color. Since these color changes often occur when vegetation is stored other than in a landfill, it is not certain what changes in vegetation could be attributed to the landfill.

i. Readability. The readability of printed matter (newsprint, paper container labels, can labels, glass labels, etc.) was not significantly altered. In some cases, newsprint and paper print was blurred due to moisture.

j. Biodegradeability. No evidence of biodegradation nor oxidation was observed for textiles, plastic, leather, wood, metal, glass and ceramics. Newsprint, cardboard and miscellaneous paper exhibited a slight to moderate decrease in strength when pulled by hand. Grass, leaves and tree and shrub prunings showed slight to moderate biodegradation. Food was seldom found and was deteriorated when observed. No observable difference was detected in biodegradation between bore holes with different fill materials.

TABLE VIII-13
BOD$_5$ OF LEACHATES FROM SELECTED LANDFILL CORE SAMPLES

Fresh sludge/waste			Sludge/waste-old fill			Solid waste only		
Days since landfilled	Sample depth, ft	BOD$_5$ mg/l	Days since landfilled	Sample depth, ft	BOD$_5$ mg/l	Days since landfilled	Sample depth, ft	BOD$_5$ mg/l
0-7	4	498	140	4	37 #	195	4	407
	8	173		10	207		8	283
	14	253		12	234		12	253
	16	70 *		18	215			
	20	399 +						
0-7	4	620	208	4	450	263	4	380
	6	500		10	300		10	750
	22	600		16	900			
14	6	133	276	4	116	321	6	28
	12	68		12	31		8	106
							12	49

* Sample had weak odor. Material consisted of paper, grass and twigs.

+ Sample has strong, sweet odor. Contained large amount of sludge and mixed dirt.

# Sample was dry and had negligible odor.

k. Gas Analyses. Analyses of gas samples taken from landfill bore holes (until the probes were destroyed during filling) are given in Table VIII-14. The freshly placed sludge/waste fill showed the greatest production of CO_2 and CH_4 on the first day of sampling. The probe was inserted at the fill working face and was destroyed prior to the next sampling period. The gas analyses from the other two probes show constantly increasing concentrations of CH_4 and to some extent CO_2. Of note is that the old sludge/waste fill had consistently higher concentrations of CO_2 and CH_4 than were found in the probe with solid waste (no sludge). The indication is that the sludge/waste fill undergoes more rapid bio-oxidation than solid waste without sludge.

5. Time and Motion Studies. Landfill dozer operations were timed during solid waste landfilling without sludge and with sludge. The overall results are presented in Table VIII-15.

Data is given separately for working refuse (includes working refuse and related travel) and for moving soil (placing soil on fill, carrying soil to fill, and related travel). Travel occurs when the dozer is not on or pushing solid waste (working refuse), or not carrying or placing soil.

It is apparent that the two dozer drivers differ significantly in non-productive time. The difference in non-productive time is not attributable to the two dozer models used since the non-productive percentages for each driver are about equal for each dozer. In order to determine if significant differences occur in working solid waste for each dozer the non-productive time was omitted and the data summarized for each driver. The results given in Table VIII-16 indicate that the two dozers were apparently similar in performance for each driver when working solid waste. Although the differences in drivers appears to be the significant variable, the data will be summarized separately for each driver and dozer.

Also, since the landfill working face was not covered daily prior to October 1972, the extra work to cover daily will probably change the percentage of non-productive time and time spent moving soil. The following discussions summarize the results for different landfill conditions. Data is presented for working refuse and travel during working refuse. It is assumed that the sludge will not affect travel time because the dozer is not working refuse when traveling. Therefore, slippage or other decreases in operating efficiency will be reflected in a higher percentage of time spent working the refuse. Statistical analyses of the results will be completed for the final report when more data is available.

a. Normal Solid Waste Landfilling. The individual and average percentage times for working refuse and related travel are given in Table VIII- 17by dozer and driver. The variation between drivers and dozers is not great. On the average, 55 to 59 percent of the time is spent actually working refuse while 41 to 45 percent is spent in related travel.

TABLE VIII- 14

LANDFILL BORE HOLE GAS ANALYSES

	Concentration, percent by volume *														
	Fresh sludge waste fill					Old sludge/waste fill					Old solid waste fill				
Date sampled	Days since placing fill	CO_2	O_2	N_2	CH_4	Days since placing fill$^+$	CO_2	O_2	N_2	CH_4	Days since placing fill$^+$	CO_2	O_2	N_2	CH_4
1972															
7-26#	0-7	75.6	1.6	6.9	15.0	140	42.2	6.6	49.0	2.2	195	28.6	4.6	66.4	0.4
8-11		Probe destroyed				156	63.4	4.8	28.6	3.2	211	45.1	0.8	53.2	0.9
8-18						163	70.7	0.6	20.4	8.3	218	44.6	1.6	52.2	1.6
9-1						177	66.5	2.5	23.6	7.4	232	50.2	2.0	43.2	4.6
9-15						191	70.2	0.4	17.4	12.0	246	52.0	2.9	34.1	11.0
10-2						208	70.3	0.0	13.7	16.0	263	Probe destroyed			
10-27						233	57.1	4.4	19.4	19.1					

* All samples taken from a depth of 10 feet below the cover soil surface.

+ Estimated.

# Probes placed July 26, 1972.

TABLE VIII-15

OVERALL TIME/TASK PERFORMANCE

Dozer/ driver no. *	Percentage of time spent on each task					
		Working refuse			Moving soil	
	Non-productive	Working refuse	Travel	Placing soil cover	Moving soil	Travel
CAT 977						
A	49	22	13	1	8	7
B	19	28	23	6	12	13
CAT 977 K						
A	49	33	13	neg	4	1
B	21	29	19	3	16	11

* Driver A is the principal dozer operator.

TABLE VIII-16
TIME/TASK PERFORMANCE EXCLUDING NON-PRODUCTIVE

Dozer/ driver no.	Percent of time spent on each task				
	Working refuse			Moving soil	
	Working refuse	Travel	Placing soil cover	Moving soil	Travel
CAT 977					
A	68	32	5	54	41
B	60	40	17	40	43
CAT 977 K					
A	76	24	11	71	18
B	60	40	9	54	37

TABLE VIII-17
TIME/TASK PERFORMANCE COMPARISONS

Landfill condition	Dozer/ driver	Percent of time *	
		Working refuse	Travel
A. Normal solid waste landfilling (no sludge)	CAT 977		
	A	52	48
	B	56	44
	avg	55	45
	CAT 977 K		
	A	58	42
	B	60	40
	avg	59	41
B. Sludge admixed with solid waste (0.5 to 0.6 lb per lb)	CAT 977		
	A	52	48
	CAT 977 K		
	A	79	21
	B	59	41
C. Double sludge admixture (1.0 to 1.2 lb per lb)	CAT 977		
	A	67	33
	CAT 977 K		
	A	69	31

---

* Based on time for working refuse and travel related to working refuse. Excludes non-productive time and time associated with moving soil.

b. Sludge Admixed With Solid Waste. The admixture of sludge with solid waste at the ratio of 0.5 to 0.6 lb sludge per lb dry weight solid waste is presented in Table VIII-17. There does not appear to be any difference in percentage of time actually spent working the refuse except for driver A using the CAT 977 K. It is not apparent why there is a significant increase in percentage of time spent by driver A, CAT 977 K working refuse, except that the driver may have been doing more compacting than he normally does.

c. Double Sludge Admixture. Special tests were conducted with double the normal sludge to waste ratio (1.0 to 1.2 lb per lb). As indicated in Table VIII-17, the time spent in working refuse increased significantly over normal solid waste landfilling, and over sludge admixed at 0.5 to 0.6 lb per lb. It is apparent that a loss in dozer efficiency occurs with increasing sludge to solid waste admixture ratios. Further field tests will be conducted during Year 03 to approximate the sludge/waste ratio where efficiency is significantly affected. The installation of the landfill truck scale will provide accurate sludge and solid waste weight data that previously was unavailable.

6. Landfill Disposal Costs. The cost of landfill disposal operations with and without sludge were estimated for 1971 without sludge, and for the first eight months of 1972 for which cost data on full scale sludge disposal was available. These costs on a ton of solid waste disposed basis are estimated from quarterly waste disposal vehicle weighings completed during 1971. The cost in 1971 was estimated at $1.23 per ton disposed, and for 1972 $1.33 per ton of solid waste (wet wt). The increase in cost for 1972 does not account for a probable increase in solid waste disposed. A comparison will be made between 1971 with no sludge, and 1973 with sludge. The quarterly waste weighings from 1971, and the daily weighings using the new landfill truck scale in 1973 will provide a more accurate cost comparison.

7. Sludge Disposal Costs. The cost of full scale truck haul disposal of liquid sewage sludge into the landfill was estimated for the period of full-scale sludge disposal (February 1972 to August 1972) for which cost data was available. Truck costs were based on the purchase price of the 3,500 gallon tank truck ($12,247.20) amortized over a 10-year life at six percent ($1,664 per year or $139 per month). Labor, repairs, fuel, etc. costs were obtained from the Oceanside Sewer Department. The costs were estimated at $2.85 per 1,000 gallons of liquid sludge or $12.64 per ton of dry sludge solids.

8. Summary. Since large quantities of sewage sludge are used throughout the country as a soil conditioner, numerous people are exposed to it. Much of this sludge is known to contain some raw waste material and pathogens. There is no record of disease transmission to humans as a result of sludge treatment plant activities and use of the sludge as a fertilizer. Burd points out that this may be due to existing health department regulations and operator precautions. There does not appear to be an urgent apparent problem regarding disinfection.

The preliminary field demonstration results presented in this chapter indicate that the joint disposal of Oceanside's digested sewage sludge and solid waste into a sanitary landfill can be accomplished successfully without major operational cost increase or difficulties. From the standpoint of landfill operation, the addition of digested sewage sludge to refuse could be beneficial in at least three respects. First, the refuse-sludge mixture could be better compacted by heavy equipment than the solid waste alone. This will be studied during Year 03. Second, the presence of sludge essentially prevents blowing of the litter which normally occurs in a refuse landfill and which may be otherwise controlled by addition of water. Third, digested sludge may possibly provide a deterrent to rodents which ordinarily abound in a refuse landfill. The demonstration work conducted to date at Oceanside has indicated the need for improved sludge-spreading techniques. Further effort is being directed toward this objective. Other aspects of sludge disposal which will be studied in the remainder of this demonstration program will include evaluation of the potential health hazards of digested sludge arising from the presence of pathogenic bacteria and viruses and fly emergence.

When undigested or partially digested liquid sewage sludge was disposed into the landfill severe odor problems resulted. By immediately covering the non-digested sludge with solid waste and a minimum 6-inches of cover soil, the odors can be controlled. Other methods of controlling odors will also be investigated during the third year.

IX. ECONOMIC ANALYSIS OF SLUDGE TRANSPORTATION ALTERNATIVES

Liquid sludge handling and disposal into a sanitary landfill consists of two steps: transportation from the sewage treatment plant to the landfill, and spreading the sludge onto the waste fill. Two feasible transportation alternatives for Oceanside are via pipeline or tank truck haul. The following is a preliminary economic analysis of the two transportation systems for future sludge disposal from two plants.

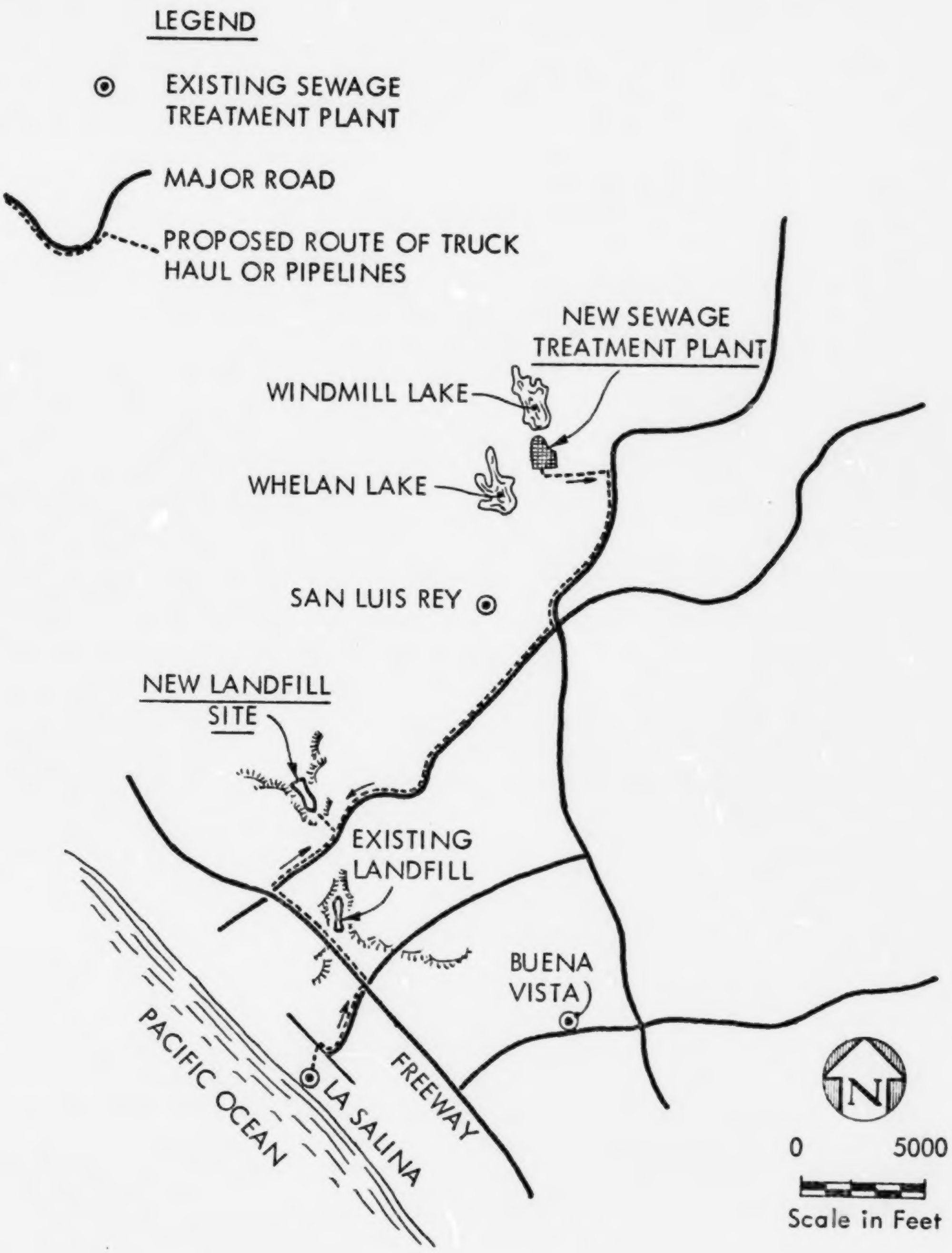
A. Basic Assumptions and Considerations

Figure IX-1 shows the locations of the landfills, the three existing sewage treatment facilities, and a new planned sewage treatment facility. When constructed, the new treatment plant will replace the San Luis Rey and Buena Vista facilities. Therefore, sludge transport from these two plants was not considered in cost determinations. The sludge from this plant and from the La Salina Plant will be transported to the new landfill. The most direct potential truck routes are indicated in Figure IX-1. It is assumed that a pipeline would follow these routes very closely, within the existing municipal right-of-way, so that no costs are incurred for additional right-of-way acquisition. Data on present and projected future sludge quantities from each plant are presented in Table IX-1 along with information on sludge solids content and transportation distances.

B. Truck Transportation

Three types of trucks were considered in the economic analysis. These are "spreader", "refueler", and "vacuum pumper". The first two types of trucks are manufactured by the Vendoro Company (Los Angeles, California) which produces a wide variety of vehicles for hauling water and fuel. The "spreader" model is a standard water truck whereas the "refueler" is a fuel truck. Both of these vehicles have to be slightly modified for sludge trucking. The modification would consist of replacing the standard water or jet fuel pump with a heavy duty sludge pump, and providing multiple spreading nozzles. The costs of spreading nozzles and pumps (or elimination of pumps, if gravity loading and dumping are employed) are small compared to the total cost and, hence, were disregarded in this preliminary economic analysis. Currently, there are some 3,000 "vacuum pumper" trucks in operation across the nation, with approximately 150 in Los Angeles County, California, alone.[34] These trucks are used primarily to haul industrial waste type liquid residues.

Table IX-2 presents a summary of estimated sludge hauling costs for the three types of trucks considered. A hauling time of 1 hr was assumed (10 min each for loading and unloading, and 40 min for an average round-trip from either the La Salina or the new San Luis Rey treatment plant to the new landfill). As indicated in Table IX-2, the total estimated annual capital and operating costs for sludge transportation with "spreader", "refueler", and "vacuum pumper" trucks are about \$36,400, \$14,000, and \$19,500, respectively. The use of a refueler truck thus appears to be economically most advantageous.


LEGEND
EXISTING SEWAGE TREATMENT PLANT
MAJOR ROAD
PROPOSED ROUTE OF TRUCK HAUL OR PIPELINES
NEW SEWAGE TREATMENT PLANT
WINDMILL LAKE
WHELAN LAKE
SAN LUIS REY
NEW LANDFILL SITE
EXISTING LANDFILL
BUENA VISTA
FREEWAY
LA SALINA
PACIFIC OCEAN
N
0
5000
Scale in Feet

CITY OF OCEANSIDE/E.P.A.

FIGURE IX-1
POSSIBLE ROUTINGS FOR SLUDGE
PIPELINE OR TRUCK HAUL

TABLE IX-1
BASIS OF COST ESTIMATES FOR TRUCKING OR PIPELINING LIQUID DIGESTED SLUDGE IN OCEANSIDE[*]

Digested sludge	La Salina plant	San Luis Rey and Buena Vista	New plant	Total
1968-1969				
Million gallons/year	1.892	.7353	0	2.627
% Solids				
Average	3.0	4.9	-	-
Range	2.2-3.5	1.9-14.7	-	-
Projected, 1985				
Million gallons/year	2.2[+]	0	8.4[#]	10.6
% Solids				
Average	3.0	-	5.5	-
Range	-	-	-	5.0-6.0
Tons/year, solids	277.[**]	0	1,940[**]	2,217
Gallons/day, liquid	8,420[++]	0	32,300[++]	
Approximate miles to landfill site	2	-	5	-
Ton-miles/year (dry-weight basis)	554	-	9,700	10,254

[*] From reference 7.

[+] Present capacity, increased by 15%, rounded off.

[#] By difference.

[**] Based on average % solids and assumed liquid weight of 8.4 lbs/gal.

[++] Based on 5 days/week, 52 weeks/year.

TABLE IX-2
COST OF TRUCKING SLUDGE - OCEANSIDE

	Spreader *	Refueler *	Vacuum pumper +
Capacity (gallons)	3,300	10,000	7,000
Cost range ($1,000)			
Truck	18-25	-	-
Tank & modification	10	-	-
Total	28-35	50	40-50
High average	32	50	45
Loads/Day			
La Salina (8,420 gallons/day)	3-	1	2-
New plant (32,300 gallons/day)	11-	3¼	5-
Total	14-	4¼	7-
No. of trucks required	2	½	1
Annual costs ($1,000)			
Depreciation (10-year basis) **	6.4	5.0#	4.5
Fuel & maintenance **	6.0	3.0#	3.0
Driver's salary & fringe, & overhead(5) ++	24.0	6.0#	12.0
Total annual cost	36.4	14.0	19.5

(Cont'd)

TABLE IX-2 (CONT.)

	Spreader *	Refueler *	Vacuum pumper +
Average cost/ton, $ of liquid as hauled	0.81	.32	0.43
Average cost/ton, $ of solids/ton, dry basis ##	18.10	6.32	8.80
Average cost/ton-mile, dry basis ***	3.90	1.38	1.90

* Characteristic truck data from Klein products.

+ From Reference 8.

# It is assumed that the total depreciation on the truck will be charged to the sludge hauling operation, while the driver's salary will only apply for the half of the time that the truck is used to haul sludge.

** Basis: $3,050 annual average for Oceanside refuse collection trucks, which is probably high due to the larger number of moving parts than on a liquid tanker, and assumed applicable to all sizes of tankers.

++ Basis: $10,000/man-year + 20% fringe and overhead.

## Basis: 2,217 tons/year of dry solids.

*** Weighted average haul of 277 tons x 2 miles and 1,940 tons x 5 miles is 4.63 miles.

C. Pipelines

Table IX-3 presents a summary of the estimated costs for sludge transportation by pipelines. Due to the smaller flow from the La Salina plant, the cost of the 2-mi pipeline from this plant has been considered separately from that of the 5-mi line from the new plant.

The following assumptions were made:

a) The pipeline follows the same route as the truck hauls (see Figure IX-1).
b) The pipeline will be 8-in. in diameter.
c) The entire daily sludge production will be pumped to the landfill over a sufficiently short period of time (less than 10 percent of the time) so that adequate flow velocities can be maintained to avoid deposition of sludge solids in the pipeline.
d) Sludges from the La Salina and the new plant will contain about 3.0 and 5.5 percent solids, respectively.
e) The trucks and the pumping system (pipes and associated pumps) would have useful lives of 10 and 30 years, respectively.
f) The maintenance cost for the pipeline would be negligible. The maintenance cost for the pumps was included in the treatment cost at the sewage treatment plants.
g) The pipeline and the pumping station first costs were about $10 per running foot and $50,000, respectively.
h) Sludge would be applied directly to the solid waste without storage at the landfill.

The data in Table IX-3 indicate that the sludge transportation by pipelines would cost $1.08 and $9.37 per ton of dry solids per mile for the new plant and La Salina, respectively. Comparison of these values with the corresponding estimates for truck transportation ($1.38-$3.90 per ton of dry solid per mile), indicates that the pipeline from the La Salina plant is decidedly not economical, while the pipeline from the new plant is competitive with trucking. This would suggest that the optimum economy may involve a pipeline service to the new treatment plant and sludge hauling for the La Salina plant.

It should be emphasized that the economic analysis presented here is only preliminary and was based on a large number of assumptions, the validity of which have not been fully established. For example, sludge transportation cost is affected significantly by the sludge solids content and at the present time the solids content of the sludge which will result from the operation in the new plant is not specifically known. It is estimated that an increase in the sludge solids content from 2.2 to 6 percent would reduce the transportation cost (by either trucking or pipeline) by approximately 63 percent.

TABLE IX-3

COSTS OF PIPELINE TRANSPORTATION - OCEANSIDE

	La Salina	New plant
Distance from landfill (miles)	2	5
Annual sludge production		
Million gallons	2.2	8.4
Tons (liquid)	9,230	35,300
Tons (solids only)	277.	1,940
Cost of pipeline ($)	105,600	264,000
Cost of pumping station ($)	50,000	50,000
Total	155,600	314,000
Annual depreciation (30-year basis) ($)	5,186	10,466
Cost per ton ($)		
Liquid sludge basis	.56	.295
Dry solids basis	18.75	5.40
Cost per ton-mile ($) solids only.	9.37	1.08

In recent years several studies have been reported in the literature on sludge transportation costs. One study[1] reports a long-term pipeline transportation cost of \$3 to \$7 per ton of dry solids of which \$1 to \$2 is charged to operation and maintenance. This study assumes pipe lengths of 4 to 17 miles and diameters of 8 to 24 inches. A study of sludge transportation in the Chicago area[35] indicates costs of \$37.50 and \$6.80 per ton of dry solids for truck hauling and pipeline respectively. The Chicago study was based on employing 14- and 24-in. pipelines flowing at their optimum capacity for 95 percent of the time. Although the sludge quantities and conditions assumed in these studies are significantly different from those used in the preliminary analysis for Oceanside, the reported data are generally in reasonable agreement with those for Oceanside (especially the pipeline transportation costs).

In conclusion, the preliminary economic analysis reported here for Oceanside indicates that a pipeline from the new San Luis Rey treatment plant to the new landfill site may be economically justified in lieu of truck transportation of sludge. In the case of the La Salina plant, however, truck hauling appears more economical than pipeline transportation. As conditions change with time, further analysis should precede the final selection of an appropriate sludge transportation system for Oceanside.

REFERENCES

1. Burd, R. S. A study of sludge handling and disposal. Water Pollution Control Research Series, FWPCA Publication No. WP-20-4. Washington, U.S. Federal Water Pollution Control Administration, 1968. 326 p.

2. Black, R. J. Combined disposal of sewage sludge and refuse. Compost Science, 2(4):16-17, Winter 1962.

3. Standard methods for the examination of water and wastewater. 13th ed. New York, American Public Health Association, 1971. 874 p.

4. Hanks, T. G. Solid waste/disease relationships, a literature survey. Public Health Service Publication No. 999-UIH-6. Washington, U.S. Government Printing Office, 1967. p.50-51.

5. Smith, D. T., N. F. Conant, H. P. Willett, J. W. Beard, et al. Zinsser Micriobology. 14th ed. New York, Appleton-Centure-Crofts, 1968. 1,281 p.

6. Hanks, Solid waste/disease relationships, p.51 and p.73-74.

*7. Clarke, op. cit. p.249.

8. Brezenski, F. T., R. Russomanno, and P. DeFalco, Jr. The occurrence of salmonella and shigella in post-chlorinated and non-chlorinated sewage effluents and receiving waters. Health Laboratory Science, 2(1):40-47, 1965.

9. Klein, L. River pollution. III. Control. London, Butterworth & Company, 1966. 484 p.

10. Anderson, M. S. Fertilizing characteristics of sewage sludge. Sewage and Industrial Wastes, 31(6):678-682, June 1959.

11. Gotaas, H. B. Composting; sanitary disposal and reclamation of organic waste. Monograph Series No. 31. Geneva, World Health Organization, 1956. 205 p.

12. Golueke, C. G. Public health aspects of waste disposal by composting. American Journal of Public Health, 44:339-348, Mar. 1954.

13. Stone, R., and R. K. Gupta. Aerobic and anaerobic landfill stabilization process. Journal of the Sanitary Engineering Division, Proceedings, American Society of Civil Engineers, 96(SA6):1,399-1,414, Dec. 1970.

14. Zanoni, A. E. Ground water pollution from sanitary landfills and refuse dump grounds; a critical review. Research Report 69. Madison, Wisconsin Department of Natural Resources, 1971. 43 p.

15. Qasim, S. R., and J. C. Burchinal. Leaching from simulated landfills. Water Pollution Control Federal Journal, 42(3):371-379, Mar. 1970.

16. Cook, H. A., D. L. Cromwell, and H. A. Wilson. Microorganisms in household refuse and seepage water from sanitary landfills. Proceedings, West Virginia Academy of Sciences, 39:107-114, 1967.

17. Huebner, R. J., W. J. Jellison, and C. Pomerantz. Rickettsialpox: a newly recognized rickettsial disease, part 4. Public Health Reports, 61(47):1,677-1,682, Nov. 22, 1946.

18. Clarke, N. A., and P. W. Kabler. The inactivation of purified coxsackie virus in water by chlorine. American Journal of Hygiene, 59:119-127, 1954.

19. American Public Works Association. Municipal refuse disposal. 3d ed. Chicago, Public Administration Service, 1970. 538 p.

20. Cummins, R. L. Effects of land disposal of solid waste on water quality. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. 29 p.

21. Qasim, and Burchinal, Leaching from simulated landfills, p.379.

22. Anderson, op. cit., p.30.

23. Rules and regulations for administration of the Pennsylvania Solid Waste Management Act of July 31, 1968 [Act 24]. Title 25 of rules and regulations, sub-part C, article I. [Harrisburg], Pennsylvania Department of Environmental Resources, Aug. 2, 1971. [19 p.]

24. Status of solid waste management in California. v.1. Interim report. California State Department of Public Health, 1968.

25. Andersen, R. L., et al. Utilization of municipal wastewater sludge. Journal of the Water Pollution Control Federation, 29, 1971.

26. American Public Works Association, Municipal refuse disposal, 1970.

27. Merz, R. C., and R. Stone. Factors controlling utilization of sanitary landfill site: final report to U.S. Department of Health, Education, and Welfare, Jan. 1964 to Dec. 31, 1965. Los Angeles, University of Southern California. (Limited distribution).

28. Fungaroli, A. A. Pollution of subsurface water by sanitary landfills. v.1. Washington, U.S. Government Printing Office, 1971. [200 p.]

29. Black, R. J., and A. M. Barnes. Effect of earth cover on fly emergence fron sanitary landfills. Public Works, 89(2):91-94, Feb. 1958.

30. Fuller, J. E., and W. Litsky. *Escherichia coli* in digested sludge. Sewage and Industrial Wastes, 22:853-859, 1950.

*31. Keller, P. Sterilization of sewage sludges. Public Health, (South Africa) 15(1):11, 1951.

32. Keller, P. Part 2--the influence of heat treatment on the ova of *Ascaris lumbricoides* in sewage. Journal and Proceedings, Institute of Sewage Purification, Part 1:100-109, 1951.

33. Peterson, M. L. Pathogens associated with solid waste processing; a progress report. Washington, U.S. Environmental Protection Agency, 1971. 24 p.

34. Stone, R. Sanitary landfill disposal of chemical and petroleum waste. American Institute of Chemical Engineers Symposium Series, 68(122): 35-59, 1972.

35. Harza Engineering Company. Land reclamation project; interim report. Cincinnati, U.S. Department of Health, Education, and Welfare, 1968. [338 p.]

36. Shell, G. L., and J. L. Boyd. Composting dewatered sewage sludge. Public Health Service Publication No. 1936. Washington, U.S. Government Printing Office, 1970. 28 p.

BIBLIOGRAPHY

Anderson, M. S. Sewage sludge for soil improvement. U.S. Department of Agriculture Circular No. 972. Washington, U.S. Government Printing Office, Nov. 1955. 27 p.

Andersson, A. Mercury in decayed sludge. *Grundforbattring,* 20(3-4): 149-150, 1967. (*Chemical Abstracts,* 69:45867d, 1968.)

Bacon, V. W., and F. E. Dalton. Professionalism and water pollution control in greater Chicago. *Journal of the Water Pollution Control Federation,* 40(9):1,586-1,600, Sept. 1968.

Blosser, R. O., and A. L. Caron. Recent progress in land disposal of mill effluents. *Tappi,* 48(5):43A-46A, May 1965.

Brisbin, S. G. Flow of concentrated raw sewage sludges in pipes. *Journal of the Sanitary Engineering Division, Proceedings, American Society of Civil Engineers,* 83(SA3):paper 1274, June 1957.

Bucksteeg, W. Disposal of inorganic contaminants. Requirements and their fulfillment. *Gas- und Wasserfach,* 108(34):962-965; (36):1,018-1,021, 1967. (*Chemical Abstracts,* 68:33010k, 1968.)

Burd, R. S. A study of sludge handling and disposal. Water Pollution Control Research Series, FWPCA Publication No. WP-20-4. Washington, U.S. Federal Water Pollution Control Administration, 1968. 326 p.

Canham, R. A. Comminuted solids inclusion with spray irrigated canning waste. *Sewage and Industrial Wastes,* 30(8):1,028-1,049, Aug. 1958.

Carpenter, W. L., and J. Grossman. Relationship of flow characteristics to changes in sludge consistency. *Tappi,* 53(1):64-66, Jan. 1970.

Cheng, D. C.-H. The flow of non-Newtonian slurries and suspensions in pipeline systems. *Filtration & Separation,* 7(4):434-440, July/Aug. 1970.

Chou, T.-L. Resistance of sewage sludge to flow in pipes. *Journal of the Sanitary Engineering Division, Proceedings, American Society of Civil Engineers,* 84(SA5):paper 1780, Sept. 1958.

Continued study of wastewater reclamation utilization. California State Water Pollution Control Board Publication No. 15. Sacramento, 1956.

Cotton, P. A survey of some sewage treatment and allied problems at Norwich, 1963-68. *Water Pollution Control,* 68(6):627-634, 1969.

Dalton, F. B., J. E. Stein, and B. T. Lynam. Land reclamation--a complete solution of the sludge and solids disposal problem. Journal of the Water Pollution Control Federation, 40(5):789-804, May 1968.

Dodson, R. E., and R. Stone. Advances in sludge disposal. Journal of the Sanitary Engineering Division, Proceedings, American Society of Civil Engineers, 88(SA4):71-72, July 1962.

*Dotson, G. K. Sludge disposal by landspreading; summary outline. Personal communication, 1971.

*Dotson, G. K., R. B. Dean, W. B. Cooke, and B. A. Kennar, Land spreading, a conserving and non-polluting method of disposing of oily wastes. Presented at 5th International Water Pollution Research Conference, San Francisco, July 21-Aug. 1, 1970.

Evans, J. O. Ultimate sludge disposal and soil improvement. Water and Wastes Engineering, 6(6):45-47, June 1969.

Ewing, B. B., and R. I. Dick. Disposal of sludge on land. In E. F. Gloyna, and W. W. Eckenfelder, Jr. Water quality improvement by physical and chemical processes. Austin, University of Texas, 1970. p.394-408.

Fisichelli, A. P. Raw sludge pumping--problems and interdisciplinary solutions. Journal of the Water Pollution Control Federation, 42(11):1,916-1,921, Nov. 1970.

*Fleming, J. R. Sludge utilization and disposal. Proceedings of the 8th Southern Municipal and Industrial Waste Conference, p.198-218, 1959.

FWPCA waste management study. v.1. The waste management concept; inland and ocean disposal of selected wastes. San Francisco, Bechtel, Incorporated, 1969. 167 p.

Gothard, S. A. Garbage processing in Jersey, British Isles. Compost Science, 2(1):7-11, Spring 1961.

Habs, H. Should sewage sludge be treated hygienically. Staedtehygiene, 21:185-161, 1970. (Water Pollution Abstracts, 43:1770, Sept. 1970.)

Hajek, B. F. Chemical interactions of wastewater in a soil environment. Journal of the Water Pollution Control Federation, 41(10):1,775-1,786, Oct. 1969.

Hinesly, T. D., and B. Sosewitz. Digested sludge disposal on crop land. Journal of the Water Pollution Control Federation, 41(5):822-830, May 1969.

Hornig, G. Gegenwaertiger Stand der Bemessungsverfahren fuer den hydraulischen Schlammtransport im Hinblick auf die landwirtschaftliche Verwertung. [Present status of methods for dimensioning hydraulic sludge transportation with respect to agricultural uses.] Wasserwirtschaft-Wassertechnik, 18(3):94-99, 1968.

BIBLIOGRAPHY (Cont.)

*Jansson, S. L. On the humus properties of organic manures. I. Actual humus properties. Lantbrukshogskolans Annaler, 26:51, 1969.

*Jansson, S. L. On the humus properties of organic manures. II. Potential humus properties. Lantbrukshogskolans Annaler, 26:135, 1969.

Increased income from sludge spraying. Water & Waste Treatment Journal, 12(1):32, May/June 1968.

Krups'kli, M. K., and P. A. Gasan. Prevention of filtration of industrial waste waters from settlers by the method of coagulation colmatage. Agrokhimiya i Gruntoznavstvo, no.2:141-148, 1966. (Chemical Abstracts, 68:6016k, 1968.)

Kumke, G. W., J. F. Hall, and R. W. Oeben. Conversion to activated sludge at Union Carbide's Institute plant. Journal of the Water Pollution Control Federation, 40(8):1,408-1,422, Aug. 1968.

Lunt, H. A. Digested sewage sludge for soil improvement. Connecticut Agricultural Experiment Station Bulletin 622. New Haven, Apr. 1959. 30 p.

*MacLaren, J. W. Evaluation of sludge treatment and disposal. Canadian Municipal Utilities, 23-33, 51-59, May 1961.

Merkel, W. The flow characteristics of sewage sludge and other thick materials. Physics, 5:355-361, Nov. 1934.

Nusbau, I., and L. Cook, Jr. Making topsoil with wet sludge. Wastes Engineering, 31(8):438-440, Aug. 1960.

*Premi, P. R., and A. H. Comfield. Incubation study of nitrification of digested sewage sludge added to soil. Soil Biology and Biochemistry, 1:1, 1969.

Raynes, B. C. Economic transport of digested sludge slurries. Journal of the Water Pollution Control Federation, 42(7):1,379-1,386, July 1970.

Riddell, M. D. R., and J. W. Cormack. Selection of disposal methods for wastewater treatment plants. In Waste Disposal from Water and Wastewater Treatment Processes; Proceedings; 10th Sanitary Engineering Conference, University of Illinois Department of Civil Engineering, 1968. p.131.

Rose, B. A. Sanitary district puts sludge to work in land reclamation. Water & Sewage Works, 115(9):393-399, Sept. 1968.

Rudolfs, W., and L. E. West. Properties of sludge which affect its discharge through 24-inch pipe. Sewage and Industrial Wastes, 12(1):60-72, Jan. 1940.

Scanlon, A. J. Utilization of sewage sludge for the production of topsoil. Sewage and Industrial Wastes, 29(8):944-950, Aug. 1957.

Scott, R. H. Disposal of high organic content wastes on land. Journal of the Water Pollution Control Federation, 34(9):932-950, Sept. 1962.

Sharp, A. N. Trade effluent disposal by long-distance pressure pipeline system (Discussion). Institution of Civil Engineers Proceedings, 45:701-708, Apr. 1970.

Sironen, E. R., and D. Lee. Sludge density control by ultrasonics. Journal of the Water Pollution Control Federation, 42(2):298-301, Feb. 1970.

*Smith, J. C., Jr. Ultimate disposal of sludges. Technical Seminar Workshop on Advanced Waste Treatment, Chapel Hill, N.C., Feb. 9-10, 1971.

*Sparr, A. E. Pumping sludge long distances. Alexander Potter Associates, 1971.

Survey of design trends and developments for small sewage treatment plants in past decade. Wastes Engineering, 34:520-523, Oct. 1962.

Szucs, J. Use of radioisotopes for determination of the sludge level. Vodni Hospodarstvi, B 19(3):76-79, 1969. (Chemical Abstracts, 72:70395t, 1970.)

Third report on the study of waste water reclamation and utilization. California State Water Pollution Control Board Publication No. 18. Scramento, 1957. 102 p.

Thomas, R. E., and T. W. Bendixen. Degradation of wastewater organics in soil. Journal of the Water Pollution Control Federation, 41(5):808-813, May 1969.

Tigges, R. The disposal of sludges from neutralization and detoxification plants in the urban area of Duesseldorf-Mettman. Industrieabwasser, p.22-24, 1965. (Water Pollution Abstracts, 41:649, Apr. 1968.)

Troemper, A. P. Discussion of how serious is the problem. In Waste disposal from Water and Wastewater Treatment Processes; Proceedings; 10th Sanitary Engineering Conference, University of Illinois Department of Civil Engineering, 1968. p.7.

Viitasalo, I. Plant experiments with sewage sludge from Helsingfors. Grundfoerbaettring, 22(1-2):22-23, 1969. (Chemical Abstracts, 71:104965a, 1969.)

BIBLIOGRAPHY (Cont.)

Wirts, J. J. Pipe line transportation and disposal of digested sludge. Sewage and Industrial Wastes, 28(2):121-131, Feb. 1956.

Wirts, J. J. Sludge pumping through long force mains. Water & Sewage Works, 95(10):345-351, Oct. 1948.

Wolfs, J. R. Factors affecting sludge force mains. Sewage and Industrial Wastes, 22(1):1-10, Jan. 1950.

APPENDIX A

SUMMARY OF ANALYTICAL AND LABORATORY TEST PROGRAMS

TABLE A
ANALYTICAL METHODS

Parameter	Analytical Method (or instrument)	Reference* (page)
Biochemical Oxygen Demand (BOD)	Manometric BOD_5	Hach Manometric BOD Apparatus Hach Chemical Co.
Chemical Oxygen Demand (COD)	Dichromate Reflux	(p. 495)
pH value	Glass Electrode Method- Analytical Measurements Model 700	(p.276)
Specific Conductance	Conductivity Bridge Method- Yellow Springs Instrument Model 31	(p.323)
Turbidity	Nephelometric Method - Hach Turbidimeter - Model 2100	(p.349)
Metals		
Arsenic Calcium Chromium Copper Iron Lead Magnesium Manganese Zinc	Atomic Absorption Spectroscopy - Perkin-Elmer Model 290 B	Analytical Methods for Atomic Absorption Spectrophotometry Perkin-Elmer Corp. 1968 (also) (p.211 Standard Methods)

TABLE A (Cont.)
ANALYTICAL METHODS

Parameter	Analytical Method (or instrument)	Reference* (page)
Barium	Hach DR-colorimeter Turbidimetric Method	Hach Colorimeter Methods Manual Hach Chemical Co. 1971
Nitrate	Brucine Method	(p. 461)
Phosphate (Total)	Stannous Chloride Method	(p. 530)
Sulfate	Turbidimetric Method	(p. 334)
Chloride	Argentometric Method	(p. 96)
Total Nitrogen (Organic)	Kjeldahl Method	(p. 244)
Total Dissolved Solids	Filtrable Residue, Difference Method	(p. 539)
Total Solids %	Total Residue (%)	(p.540)
Total Organics	Volatile Residue (%)	(p. 540)
Total Volatile Acids	Column - Partition Chromatographic Method	(p. 577
Total Coliforms	Standard Total Coliform - MPN Tests	(p. 664)
Fecal Coliforms	Fecal Coliform MPN Procedure	(p. 669)
Fecal Streptococci	Multiple Tube Technic	(p. 689)
H_2S - Gas	Mine Safety Appliances - Universal Testing Kit #83500 with detector tubes for H_2S #87414	Mine Safety Appliances Co.

TABLE A (Cont.)
ANALYTICAL METHODS

Parameter	Analytical Method (or instrument)	Reference*(page)
Gas: CO_2 CH_4 O_2 N_2	Gas Chromatographic Method Varian Aerograph Model A90P3	(p. 546)
Hardness	EDTA Titrimetric Method	(p. 179)
Fluoride	SPADNS Method	(p. 174)
CO_2	Nomographic Determination of Free Carbon Dioxide and the three forms of Alkalinity	(p. 86)
Nitrogen (Ammonia)	Nesslerization Method	(p. 226)

---

*Standard Methods for the examination of water and wastewater, 13th Edition, APHA, AWWA, WPCF, American Public Health Association, Washington, D C. 1971.

TEST PROCEDURE FOR

MOISTURE CONTENT DETERMINATION

Samples are received in plastic bags with ties to seal airtight.

1. Remove bag tie and tag and obtain weight of sample and bag.
2. If sample is tightly packed, loosen to facilitate drying.
3. Place bag with sample in oven and dry at 102 C for approximately 24 hours.
4. Remove bag from oven and place in dessicator to cool.
5. After bag and sample have cooled (about 30 minutes), remove from dessicator and obtain weight of the dried sample and bag.
6. Remove sample from bag making sure all of sample is removed. Save sample to determine organic content.
7. Determine tare weight of bag.
8. Calculate moisture content using the following formulas:

Moisture Content, percent by dry weight=

$$\frac{(\text{tare} + \text{wet sample}) - (\text{tare} + \text{dry sample})}{(\text{tare} + \text{dry sample}) - (\text{tare})} \times 100$$

Moisture Content, percent by wet weight=

$$\frac{(\text{tare} + \text{wet sample}) - (\text{tare} + \text{dry sample})}{(\text{tare} + \text{wet sample}) - (\text{tare})} \times 100$$

CITY OF OCEANSIDE/E. P. A. BORE HOLE DRILLING PROGRAM INSTRUCTIONS

A. Drilling Instructions

1. Drill Site Location. Three sites will be selected on the landfill to include the following conditions: (1) freshly placed sludge/solid waste, 0 to 2 weeks old; (2) older sludge/solid waste placed about the same time as the test cells; and (3) old solid waste without sludge placed about the same time as the test cells. Condition (1) will be on the top of the current working face; conditions (2) and (3) will be selected on the first drilling period and first drilling period and drilling will be done in the same area in subsequent quarterly drilling periods.

One hole in each test cell to be drilled at least 15 feet from the gas and temperature probes. Bore holes to be drilled in a clockwise direction each time starting on the west side of the probes.

a. Test Cells. Drill to a 12-foot depth (10-foot depth excluding soil cover) to stay at least 3 feet above the bottom of each test cell.

b. Landfill. Locate the drill at least 15 feet from nearest canyon wall where feasible. Drill to a 20-foot depth into the waste fill or until either refusal or the bottom of the fill is encountered.

2. Drill Rig. A 12-inch auger drill bit on a 40-foot rig.

3. If obstacles are encountered while drilling in any hole, move the drill rig 5 to 10 feet and drill again.

B. Core Sampling Observations

1. Temperature. Insert thermometer into fresh waste on auger bit at two-foot intervals as bit is withdrawn in two-foot increments.

2. Odor. Describe odor at two-foot intervals as:

a. Strength. Strong, medium, weak, none.
b. Type. Earthy, pig pen, sweet, grassy, sour.

3. Color. Describe components natural if no change has occurred or as they appear if changed (faded, bleached, brighter, dulled, etc.).

4. Readability. Describe if newsprint, paper labels, etc. are readable, blurred, or unreadable.

5. Bio-degradability. Note components (cans, glass, grass, newsprint, polyethylene, sticks, etc.) degradability.

6. Appearance. Describe if waste components are dry, moist, powdery and crumbling, compact and agglomerated.

7. Samples. Fill a 1-quart sample bottle with representative wastes at two-foot intervals and check off on data sheet.

C. Backfilling

Backfill the core holes with the solid waste and soil removed from the same hole. If additional backfill material is needed, use solid waste from the existing fill face. Cover the hole with the original cover soil.

D. Core Sample Removal

The procedure to be followed is to drill into the solid waste a distance of 2 feet and remove the bit for sampling and observation of the material as described under item B, above. Clean off the drill bit and drill into the waste and remove the drill for sampling, etc. Mark the auger drill bit with emery cloth at 2-foot intervals (allow for soil cover) so that drill depth can be measured.

E. Gas Detection Tests

Gas detection tests for hydrogen sulfide and methane will be made at the 10-foot depth in the test cell bore holes and the 20-foot depth in the landfill bore holes. A plastic tube with a permeable material on one end will be lowered to the bottom of the hole and the hydrogen sulfide and methane tests made as done on the test cells.

ANALYSIS OF TEST CELL BORE HOLE SAMPLES FOR BACTERIA

COLIFORM (E. COLI), FECAL STREPTOCOCCUS, PSEUDOMONAS AERUGINOSA

Preparation of Sample for Bacterial Analysis:

Thirty grams of solid sample was withdrawn from the jar aseptically and added to a sterile 500 ml capacity bottle containing 270 ml of 0.067M cold phosphate buffer, pH 7.2. Contents of the bottle were mixed thoroughly by vigorous shaking of the bottle 50 times. The suspension was then filtered through a four layered sterile cheese cloth into another sterile empty bottle. This filtrate was used to prepare a series of decimal dilutions.

Preparation of Decimal Dilutions:

The filtered suspension prepared as noted above was diluted 1:10. Ten ml of this suspension was transferred to a dilution bottle containing 90 ml of phosphate buffer. The bottle was stoppered and shaken vigorously 25 times. This gave a 1:100 dilution. Further dilutions were made in a similar fashion up to 1:1,000,000 by transferring 10 ml portions into 90 ml sterile phosphate buffer for each subsequent dilution. These dilutions were used to inoculate a series of selected culture media for detecting various specific microorganisms as well as standard bacterial plate counts.

Bacterial Count by Pour Plate:

Each dilution bottle containing an appropriate dilution of the test sample was shaken vigorously 25 times and 1 ml portions were pipetted into each of the appropriately marked duplicate Petri plates. Fifteen ml of molten agar (Difco) prepared in accordance with Standard Methods was held at 45° C. The test sample was added to the agar in the Petri plate and mixed thoroughly with the agar by rotating and tilting the plate. The plates were allowed to solidify soon after mixing and incubated at 35 ± 0.5° C for 24 hours in an inverted position.

The bacterial colonies developed after incubation were counted and the bacterial content for each sample was computed from the plates containing 20 to 300 colonies. The colony count was computed per gram of the sample (wet weight).

Determination of Total Coliform Group by MPN Method:

Presumptive Test:

One ml portions of each decimal dilutions of each sample were inoculated into 5 lactose broth tubes in identical fermentation media (10 ml medium per tube).
The range of decimal dilutions used was 10^{-2} to 10^{-5} for each test sample. The fermentation tubes were incubated at 35 ± 0.5° C for 24 hours and examined for the presence of gas. If no gas was present the tubes were incubated for another 24-hour period. Tubes showing the presence of gas were recorded as being positive in the

presumptive test.

Confirmed Test:

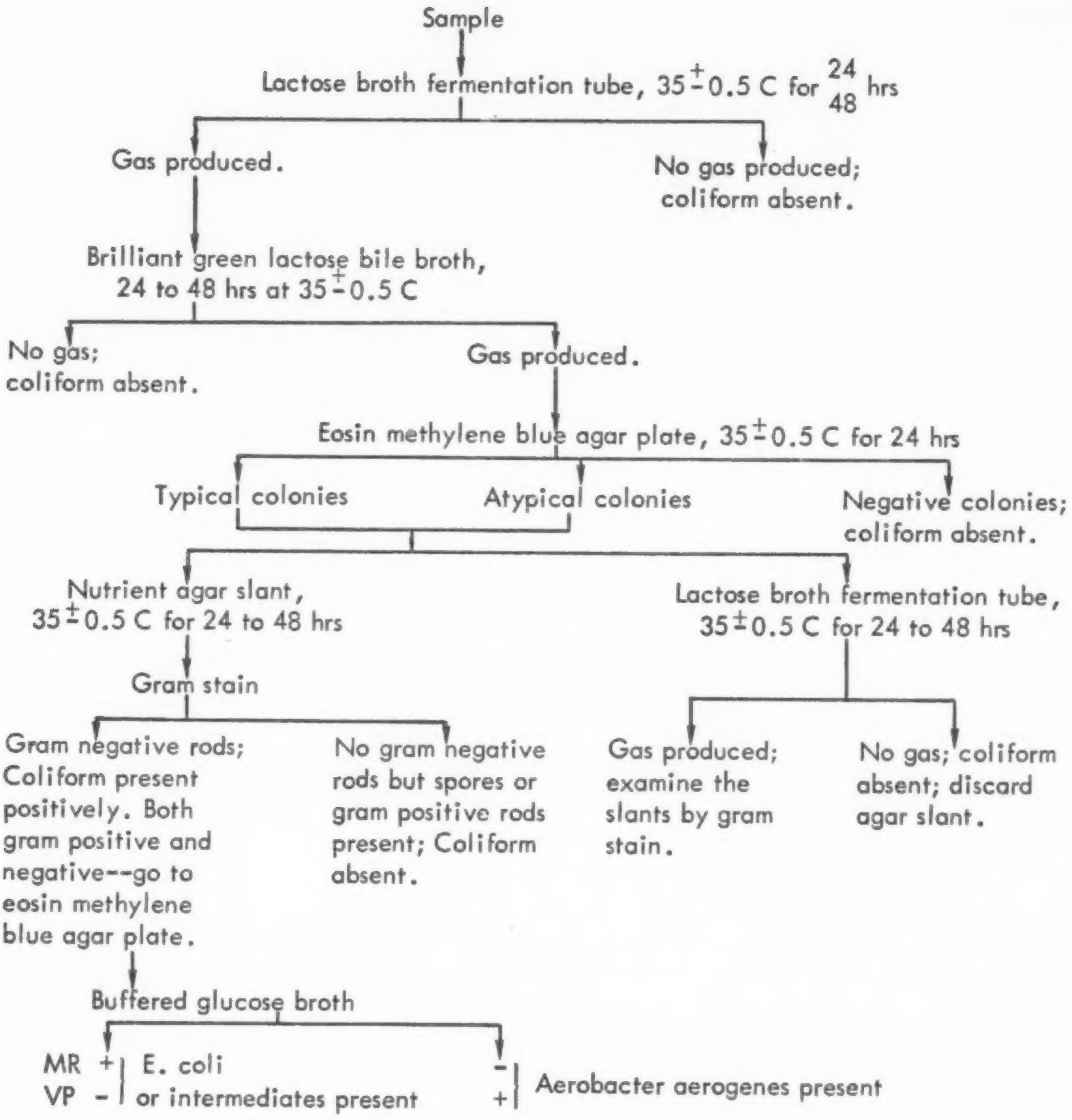
All tubes showing a positive presumptive test were submitted to a confirmation test. For this purpose a loopful (3 mm in diameter)of the culture in the presumptive fermentation tube was transferred to another fermentation tube containing brilliant green lactose bile broth. These tubes were marked appropriately and incubated at $35 \pm 0.5^{\circ}$ C. They were examined periodically for the production of gas. Tubes which did not show any gas production after 48 hours of incubation were considered negative (i.e. coliform were absent) and discarded.

Completed Test:

All brilliant green lactose bile fermentation tubes giving positive reactions within 48 hours were submitted to the confirmation test. A loopful of the culture from the confirmed test tube was streaked onto appropriately marked eosin methylene blue agar (Levine) plate soon after the production of gas. The plates were incubated in an inverted position for 24 hours at $35 \pm 0.5^{\circ}$ C and examined for the presence of typical colonies showing a green metallic sheen; atypical colonies were transferred out from the plate and inoculated into appropriately marked lactose broth fermentation tubes and nutrient agar slants. The tubes and the agar slants were incubated at $35 \pm 0.5^{\circ}$C for 24 to 48 hours. Gram stained smears were prepared from the agar slants if any amount of gas was produced in the corresponding lactose broth fermentation tubes. If no gas was produced in lactose broth fermentation tubes after 48 hours of incubation the coliform group was considered to be absent in those tubes and no gram stained smears were prepared from corresponding tubes. The gram stained smears prepared from the agar slants were examined in oil immersion under a suitable microscope for the presence or absence of spores. If the smear contained gram negative rods and no spores the test was considered to be completed, i.e. positively present coliform in the tube. If spores or gram positive rods were found on the smear the test was considered to be negative, i.e. absence of coliform bacteria in the tube. If both gram positive and gram negative rods and/or spores were found on the smear the test was considered indecisive and the procedure beginning from eosin methylene blue agar (Levine) plate was repeated.

Differential Test:

A small portion from the bacterial growth on nutrient agar slant whose smear showed gram negative rods only was inoculated into appropriately marked tubes in duplicate containing 5 ml of buffered glucose broth and incubated at $35 \pm 0.5^{\circ}$ C for 3 to 5 days. After incubation one of the duplicated tubes was treated with 5 drops of methyl red indicator solution (0.1 gram methyl red in 300 ml of 95% ethyl alcohol and diluted to 500 ml with distilled water). Development of a red color was considered as methyl red positive and development of yellow color was considered as methyl red negative.


Sample
Lactose broth fermentation tube, 35 ± 0.5 C for 24/48 hrs
Gas produced.
No gas produced; coliform absent.
Brilliant green lactose bile broth, 24 to 48 hrs at 35 ± 0.5 C
No gas; coliform absent.
Gas produced.
Eosin methylene blue agar plate, 35 ± 0.5 C for 24 hrs
Typical colonies
Atypical colonies
Negative colonies; coliform absent.
Nutrient agar slant, 35 ± 0.5 C for 24 to 48 hrs
Lactose broth fermentation tube, 35 ± 0.5 C for 24 to 48 hrs
Gram stain
Gram negative rods; Coliform present positively. Both gram positive and negative--go to eosin methylene blue agar plate.
No gram negative rods but spores or gram positive rods present; Coliform absent.
Gas produced; examine the slants by gram stain.
No gas; coliform absent; discard agar slant.
Buffered glucose broth
MR + VP - E. coli or intermediates present
MR - VP + Aerobacter aerogenes present

From: Standard Methods for Water and Wastewater Analysis, 13th Edition, AWWA, WPCF, et al, 1971.

CITY OF OCEANSIDE/E.P.A.

FIGURE 1
BACTERIAL ANALYSIS
FLOW SHEET

The other duplicate tube of the buffered glucose broth was incubated for 3 days and tested by the Voges - Proskauer test by adding 3 ml of fresh α -naphthol solution (5g in 100 ml absolute ethanol) and 1.0 ml of 40% KOH solution and incubating at room temperature for 2 to 4 hours. Development of a pink to crimson color in the culture indicated positive V-P test, otherwise the test was considered as negative. A combination of positive methyl red (MR) and negative V-P tests indicated the presence of E. coli and/or its intermediates in the tube. (The flow sheet is shown in Figure 1,)

Quantitative Analysis for Pseudomonas Aeruginosa:

Presumptive Test:

One ml portions from each decimal dilutions of each sample were inoculated into duplicate sets of 5 tubes of asparagine enrichment broth. The tubes were incubated at 35 ± 0.5°C for 48 hours. The tubes were examined for development of turbidity and/or green or blue green color. The tubes showing such characteristics were considered as positive presumptive. The negative presumptive tubes were discarded.

Confirmation Test:

The asparagine enrichment tubes, which gave positive presumptive tests were used to inoculate appropriately marked acetamide broth tubes. The acetamide broth tubes were incubated at 35 ± 0.5° C for 48 hours. Development of violet color in the medium indicated a positive confirmed test for Pseudomonas aeruginosa.

Completed Test:

Culture from positive acetamide broth (confirmation test) tubes was streaked onto appropriately marked "TECH" agar plates for isolated colonies. The plates were incubated at 35 ± 0.5° C for 24 hours. Development of diffusible blue-green color indicated the presence of Pseudomonas aeruginosa. Gram stained smears were prepared from one of these colonies and viewed in oil immersion under microscope for the presence of gram negative rods to further confirm the presence of Pseudomonas aeruginosa.

Quantitative Analysis for Fecal Streptococci:

Presumptive Test:

One ml portions of each decimal dilutions were inoculated into a series of appropriately marked azide dextrose broth tubes containing 10 ml of the medium. The tubes were incubated for 24 to 48 hours at 35 ± 0.5°C and examined for growth indicated by turbidity.

Confirmation Test:

Two drops of culture from all positive presumptive test tubes was inoculated into appropriately marked tubes containing 10 ml of ethyl violet azide broth using sterile Pasteur pipets. The tubes were incubated at 35 ± 0.5°C for 24 hours and examined for the formation of a purple button at the bottom (positive confirmation test). If tubes showed a negative confirmation test at this point, they were inoculated with an additional two drops of culture from positive presumptive test tubes, which were always saved. The confirmed test tubes were incubated again at 35 ± 0.5°C for 24 hours and examined for positive or negative reactions.

Completed Test:

Tubes of brain heart infusion broth supplemented with 6.5% sodium chloride were inoculated with three loopfuls of culture from positive presumptive tubes corresponding to positively confirmed test tubes. The completed test tubes were incubated at 35 ± 0.5°C for 48 hours and examined for growth. Turbidity in 6.5% NaCl broth constituted a completed test.

As a check, gram stained smears were prepared from 6.5% NaCl broth and viewed under a microscope.

CORE SAMPLE MOISTURE SATURATION AND LEACHATE GENERATION METHODOLOGY

1. After determination of moisture and organic content in the core samples was completed, the core samples in each bore hole having the highest and lowest moisture contents were selected for saturation and leaching tests.

2. A representative sub-sample of materials in each selected core sample was obtained and weighed.

3. The weighed sub-sample was packed into a 2-inch diameter transparent polyethylene column on top of a 1/8-inch square mesh screen support. The column system was capped at the top and bottom to close the system. A 1/16-inch I. D. glass drain tube was installed through the bottom cap. A 200-ml buret with a stop-cock control was positioned above the column with its nozzle extending through the top cap. A 200 ml graduated flask was placed below the column with the glass column drain tube passing through a rubber stopper in the top of the flask.

4. The buret was filled with 200 ml of distilled water and the stop-cock was opened to allow the water to drip into the column onto the packed solid waste material. The optimum rate of water application was determined in preliminary tests to be about 400 ml per hour. Additional distilled water was added to the buret in 100-ml portions as required to maintain a minimum of 50 ml head in the buret. Water addition required about 30 to 50 minutes to reach saturation. Saturation was indicated when prolonged dripping of water from the bottom of the sample began as determined by observation. The volume of water added to saturation (less any leachate) was determined to calculate the percent dry weight of water absorbed.

5. The water application was continued after saturation until at least 157 ml of leachate was collected in the 100 ml flask.

6. The 157 ml of leachate was used to determine BOD_5 on the HACH Manometric BOD_5 apparatus.

APPENDIX B

DATA SHEETS

WASTE SAMPLE WEIGHTS, LB

OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS
(WASTE CATEGORIES)

OBSERVER__________

DATE __________

1. Paper			2.	3.	4.	5. Garden			6.	7. Plastic Rubber Leather		8.	9.		Other
Newsprint	Cardboard (Solid and Corrugated)	Misc. Paper	Food	Glass, Ceramic	Metals	Tree & Shrub Prunnings	Leaves	Grass	Textiles	Plastic, Rubber Leather – Solid	Plastic, Rubber-Foam	Wood	Dirt, Ash, Sand	Concrete, Rock	2 Inch Sieve

Date: ____________________

Observer: ____________________

Title: ____________________

LANDFILL VEHICLE COUNT TALLY SHEET

Type and Size of Vehicle						Type of Waste Load		
Auto/ Station Wagon	Pick-up Truck Van 1/4-1 ton	Truck Over 1 ton	Waste Collection Vehicles			Domestic Household	Industrial	List Wastes & Comments
			Private/ Industrial	Oceanside Municipal	Other Municipal			

Enter check (√) or volume in cu yd if known.

Check (√) appropriate column(s).

TABLE 2

OCEANSIDE TEST CELL TEMPERATURE RECORD

Date	Temperature, Deg F									
	Ambient	Cell No. 1			Cell No. 2			Cell No. 3		
		S[1]	M-D[1]	B[1]	S	M-D	B	S	M-D	B

---

[1] S = surface probe temp; M-D = mid-depth probe temp; and B = bottom probe temp.

TABLE 3

MONTHLY OCEANSIDE TEST CELL LEACHATE SAMPLING[1]

Date	Sample No.	Quantity (gal)	BOD (mg/l)	Cl (mg/l)	TDS (mg/l)	N (mg/l)	Coliform (MPN)	EC (μmhos)

---

[1] Return each data sheet with the listed samples.

LANDFILL EQUIPMENT OPERATIONS
CITY OF OCEANSIDE

Observer ______________________

Date ______________________

Driver ______________________

Dozer ______________________

Time	Weather		Equipment Time/Task, Min. (1/100)					Flies, Rats, Birds
	Temp. °F	Condition *	Non-productive +	Working Refuse	Placing Soil Cover	Moving Earth	Travel	

*Describe weather as: (a) sunny: (b) cloudy: (c) rain; (d) wet ground (not raining).

+Include equipment maintenance, coffee/lunch breaks, breakdown/stuck, talk, etc.

FIELD TEST OF SLUDGE DISPOSAL

Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	

* Enter - Calm, Low, Moderate, or High
+ Enter - Sunny, Cloudy, Overcast, Showers, or Rain

Page ____ of ____

Date/time ______________________ **CORE SAMPLE DATA SHEET** Observer ______________________

Temp. _____ Weather ____________ Bore hole no. _____ Depth (ft) _______

Check-off when taken: Photo ( ) Sample ( ) (Take at bottom of 10 or 20 ft hole: CH_4 (mg/l) _____ H_2S (mg/l) _____)

Waste material category	Temp. (F)	Odor	Color	Readability	Appearance	Biodegradability
Newsprint						
Miscellaneous paper						
Cardboard						
Food						
Textiles						
Grass						
Leaves						
Tree & shrub prunings						
Plastic, rubber						
Leather						
Wood						
Metal						
Glass & ceramics						
Dirt, ash, sand						
Sewage sludge						

Comments ____

____

____

Continue on back

7/72 (219-0)

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL

Observer________________

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Con-dition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)

---

[*] Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

[+] Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: LS - 3 (3,500) (SD).

[#] Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer ______________

Date & time	Sludge test area: ft x ft						(No sludge) Regular landfill area: ft x ft					
	Blowing litter, no. items*	Animals and insects, no/PA+				Odor[‡]	Blowing litter no. items*	Animals and insects, no/PA+				Odor[‡]
		Birds	Rats	Flies	Others[!]			Birds	Rats	Flies	Others[!]	

* Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

[+] Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

[#] Estimate the area covered by flies and the number of flies, maggots.

[‡] Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

[!] Indicate rats, cats, dogs or other unusual animal or insect or event.

Observer________________
Date/Day________________

DS-3: LANDFILL EQUIPMENT OPERATIONS
CITY OF OCEANSIDE

Driver________________
Dozer________________

Clock			Task time, min/100								
			Equipment								Refuse condition, describe
Time (wait)	Temp (deg F)	Condition*	Nonproductive	Travel	Moving refuse	Working refuse	Moving soil	Placing soil cover	Apply water#	Unload sludge	As received, dry or wet; sludge admixed, dry or wet)

*Describe weather as: sunny; cloudy; showers; rain, overcast; wet ground.

+Nonproductive equipment time includes any time dozer motor is running, but dozer is not moving such as: equipment, repair, stuck, driver doing other tasks.

#Note if dozer driver (D) or handyman (H) is watering refuse.

CONFIDENTIAL COOPERATIVE NATIONWIDE SURVEY OF SLUDGE DISPOSAL TO SANITARY LANDFILLS

We are conducting special studies on disposal of sludges and hazardous wastes.
Please complete and return to: Ralph Stone and Company, Inc. Phone:
10954 Santa Monica Boulevard (213) 478-1501
Los Angeles, California 90025

For your cooperation in completing this questionnaire, you will receive a summary of the national results.

Landfill Location(s)______________________ Operator (name)______________
Check one: ( ) Public ( ) Private Approx. population served__________
Address______________________

1. Are any sludges, liquid wastes, or hazardous wastes disposed to the landfill? ( ) Yes (Please complete all questions.) ( ) No (Please complete questions 2, 6, 7, and 8.)

2. Is disposal of sludge, liquid wastes, or hazardous wastes to landfills regulated or inspected? ( ) Locally; ( ) State (Please enclose regulations); ( ) Unregulated; ( ) Seasonal; ( ) Routinely Performed
Comments:______________________________

3. Please estimate the following quantities:

Type of Sludge	Quantity Disposed (gal/yr)	Rate of Disposal (gal/yr)	Sludge Solids Content (%, dry weight)	Solid Waste Disposed (tons/yr)
Municipal Sewage Sludge				
Septic Tank Pumpings				
Industrial* Sludge/Liquid Waste				
Hazardous Waste *				

* Identify types, quantities of waste, and disposal locations, for radioactive, pesticides/herbicide chemicals, industrial acids and chemicals, hospital, explosives, combustibles in the space at the bottom of this page.

4. Please describe the method for applying sludge to the landfill on the back of this questionnaire.

5. Do procedures exist for the following (describe where applicable):
   a. Catching drainage from sludge overflow ( ) Yes ( ) No______________
   b. Compaction ( ) Yes ( ) No______________________
   c. Isolating landfill from contact with groundwater______________
   d. Isolating landfill from surface drainage________________

6. Type of landfill operation:
Cut and Cover ( ) Other type__________ Remaining Capacity in Fill (%)______
Canyon or ravine ( ) Fill site area (acres)________ Avg. Annual Rainfall (in.)______
Pit or Quarry ( ) Fill final depth (avg. ft.)__________

6. (Cont.)

Is refuse covered daily? ( ) Yes Depth of Cover (ft)____________( ) No

Do regulations exist on types of solid wastes accepted for landfill disposal?
( ) Yes (enclose copy) ( ) No

Is waste weighed as received at the landfill? ( ) Yes ( ) No

Approximate daily tonnage__________

Has the landfill caused local water pollution problems? ( ) Yes ( ) No

Comments:______________________________________

Have tests for leachate drainage from the landfill been made? ( ) Yes ( ) No

Describe quantity (gpd):______________________________________

7. Landfill use:

a. Is the landfill open to the public: ( ) Yes ( ) No b. How close is the nearest residential area_______c. What is the planned use for the landfill site after filling is completed?______________________________________

8. Landfill Operation Opinion Question

NOTE: If sludge is disposed to your landfill, rate the effects as requested. If sludge is not disposed to your landfill, give your opinion of the effects you would expect if it was disposed. Your opinion is being solicited to learn the prevailing attitudes of landfill operators in the 50 states as a whole.

a. Environmental Impact of Hazardous Waste Disposal

Please rate, in your opinion, the seriousness of problems and hazards associated with handling, transporting, and disposing of the following waste materials:

Type of Waste Material	Anticipated Environmental Problem/ Hazard in Transportation and Disposal Via Landfill										
	None	Little			Moderate				Great		
	0	1	2	3	4	5	6	7	8	9	10
a. Municipal Sewage Sludge											
b. Septic Tank Sludge											
c. Radioactive Waste											
d. Pesticide/Herbicide, etc.											
e. Indus.Petro,chemicals											
f. Hospital Waste											
g. Combustibles											
h. Explosives											

b. Anticipated Sanitary Landfill Effect

Please rate municipal sludge, septic tank sludge, and other liquid and hazardous waste disposal to sanitary landfill relative to sanitary landfilling without disposal of these materials for each of the following conditions·

Landfill Conditions/Factors	Rating										
	Much Worse		Slightly Worse			Same	Slightly Improved			Greatly Improved	
	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Fires											
Settlement											
Ease of Equipment Operation											
Ease of Compaction											
Compaction Density											
Operating Cost											
Blowing Dust and Litter											
Leachate Quantity											
Ground Water Quality											
Local Surface Water Pollution											
Flies											
Vermin											
Birds											
Gas Production											
Odors											
Fill Operator Health & Safety											
Public Attitudes											

Thank you very much for your assistance. Please use the space below for additional comments. Attach available reports when returning questionnaire.

File No. 219-0

CONFIDENTIAL COOPERATIVE SURVEY OF FIFTY STATES ON DISPOSAL OF SLUDGE, LIQUID OR HAZARDOUS WASTES TO SANITARY LANDFILLS

Please complete and return to:
Ralph Stone and Company, Inc.
10954 Santa Monica Boulevard
Los Angeles, California 90025
Phone:
(213) 478-1501

We are conducting special studies on disposal of sludge and hazardous wastes to landfills. The study objectives include determining public health policy on handling and disposing of sewage sludge, septic tank pumpings, and industrial sludge, liquid and hazardous wastes. Your response to this questionnaire would, therefore, be most helpful. In return for your cooperation, a summary of the questionnaire results will be mailed to your agency upon completion of the study.

Name of State____________

Optional: Name__________________Title__________Address_______________

1. Does your state permit ( ) regulate ( ) inspect ( ) or prohibit ( ) disposal of the following liquid wastes to landfills:

   Municipal Sewage Sludge__________ Industrial Sludge/Liquid Waste *__________
   Septic Tank Pumping ____________ Hazardous Waste*______________

2. Estimate number of landfill sites disposing of sludge, liquid and hazardous waste*:

   ____

3. What problems, if any, have occurred in your state because of disposing any of the waste listed in item 1 into landfills?_________________________

   ____

4. Recommended or existing alternative sludge/liquid waste disposal methods ______

   ____

5. Confidential Personal Opinion Question

   NOTE: Only your personal opinion is being solicited. ALL REPLIES TO THE FOLLOWING QUESTIONS WILL REMAIN CONFIDENTIAL. Only summary results will be published. It is understood that your rating will be a subjective, educated guess. We are primarily interested in learning the prevailing attitudes of knowledgeable Public Health/Sanitary Engineers in the 50 States as a whole.

a. Environmental Impact of Hazardous Waste Disposal

   Please rate, in your opinion, the degree of problems and hazards associated with handling and disposing of the following waste materials:

Type of Waste Material	Anticipated Environmental Problems/Hazard										
	None	Little			Moderate				Great		
	0	1	2	3	4	5	6	7	8	9	10
a. Municipal Sewage Sludge											
b. Septic Tank Sludge											
c. Radioactive Waste											
d. Pesticide/Herbicide Chemicals											
e. Industrial Acids, Chemicals, etc.											
f. Hospital Waste											
g. Combustibles											
h. Explosives											

* Identify types: radioactive, pesticides, herbicides, chemicals, industrial acids, hospital, explosives, or combustibles.

Anticipated Sanitary Landfill Effect

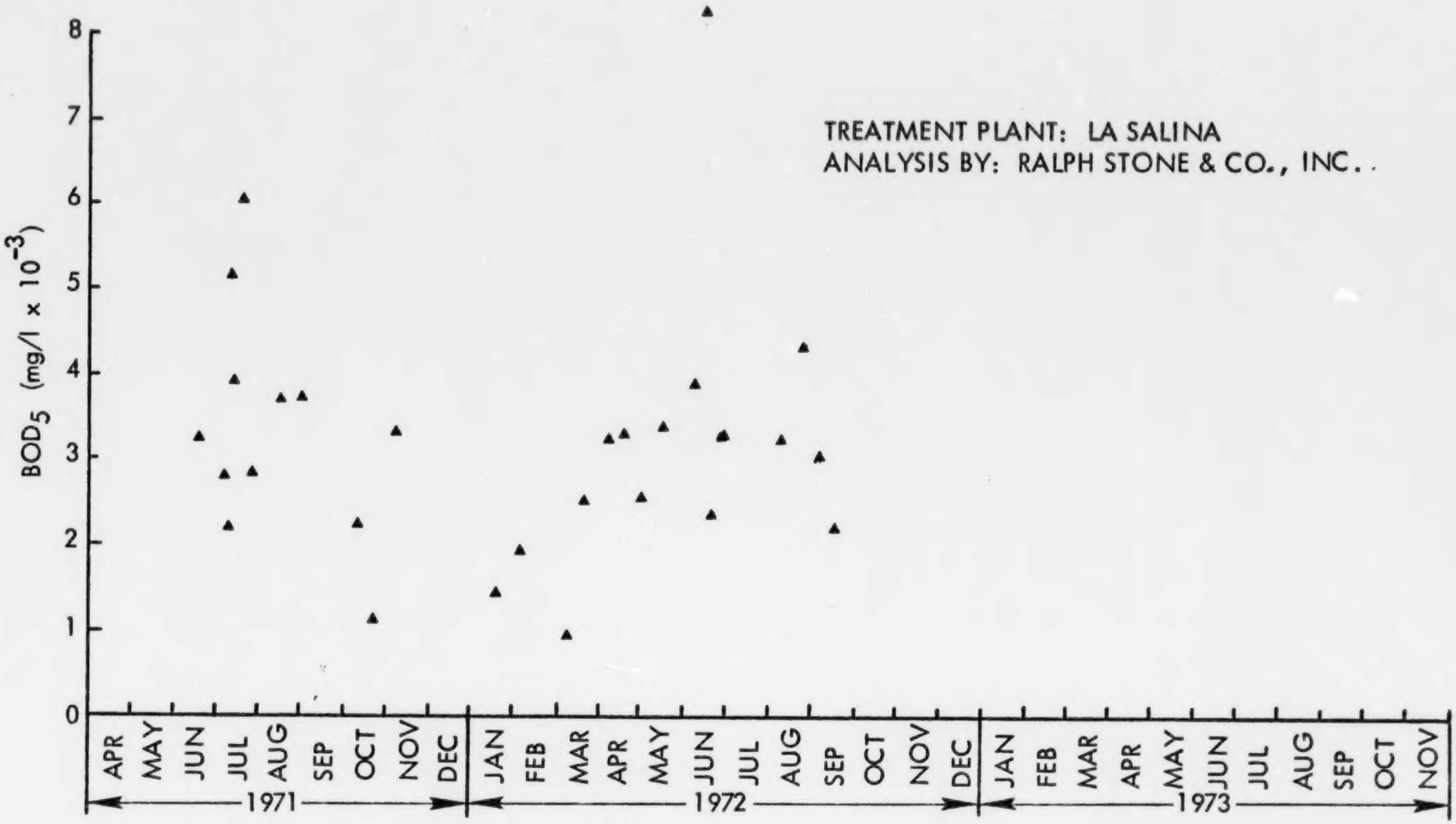
Please rate, in your opinion, the effects of disposing domestic sewage sludge, septic tank pumpings, industrial sludges*, liquid and hazardous* waste to landfills on each of the listed landfill factors.

Sanitary Landfill Conditions/Factors	Anticipated Effects of Sludge, Etc. Disposal										
	Much Worse		Slightly Worse			No Change	Slightly Improved			Greatly Improved	
	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Leachate Quantity											
Ground Water Quality											
Local Surface Water Pollution											
Gas Production											
Odors											
Flies											
Vermin											
Birds											
Fill Operator Health & Safety											
Public Attitudes											
Aquatic Life (fish)											

* We will appreciate receiving a copy of your applicable State, Health and Safety Code Regulations regarding sanitary landfills, sewage sludge, septic tank and hazardous waste disposal. Thank you very much for your assistance.

APPENDIX C

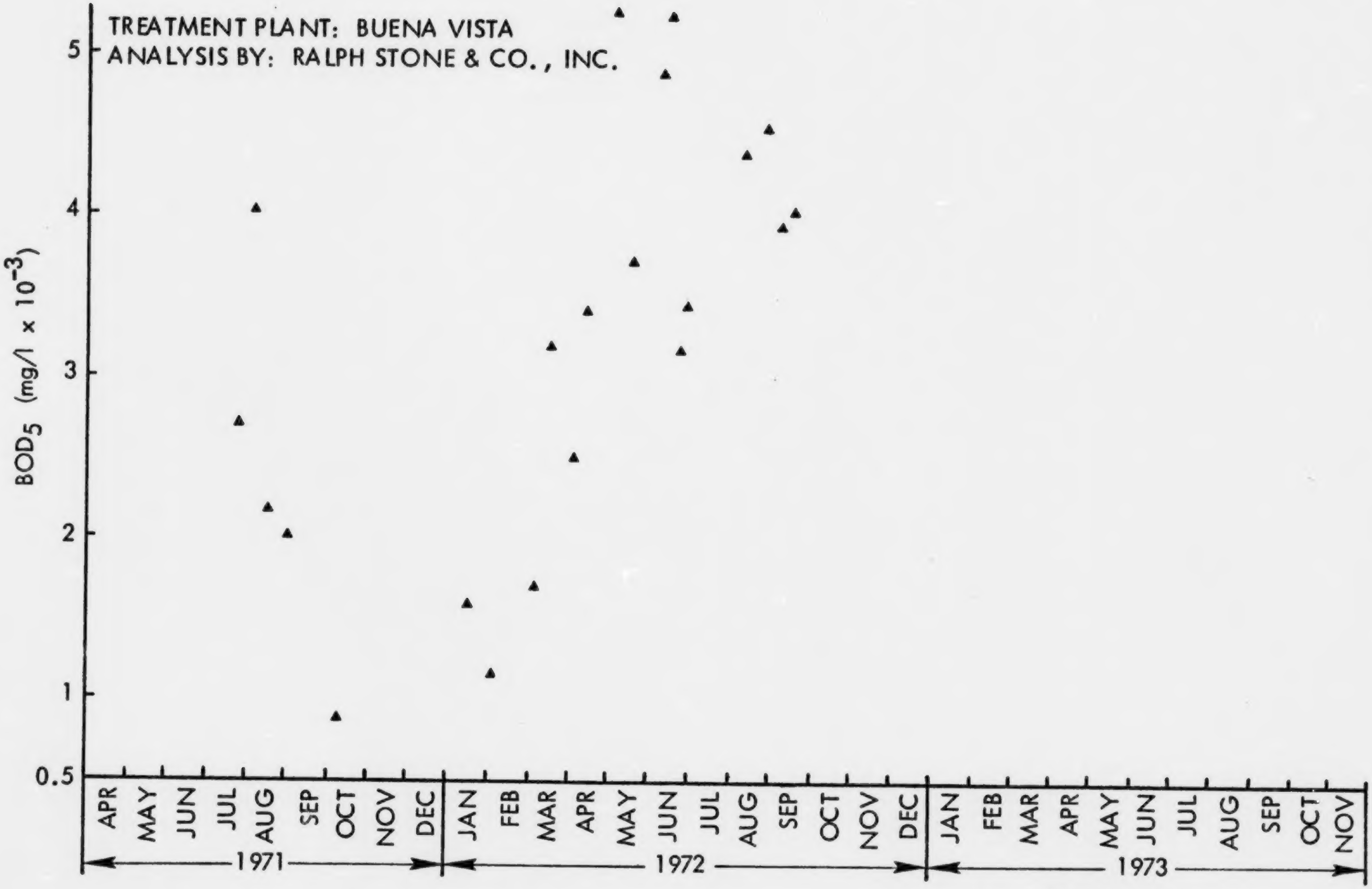
ANALYSES OF SEWAGE SLUDGES FROM OCEANSIDE, CALIFORNIA



TREATMENT PLANT: LA SALINA
ANALYSIS BY: RALPH STONE & CO., INC.

CITY OF OCEANSIDE/E.P.A.

FIGURE C1
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



CITY OF OCEANSIDE/E.P.A.

FIGURE C2
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

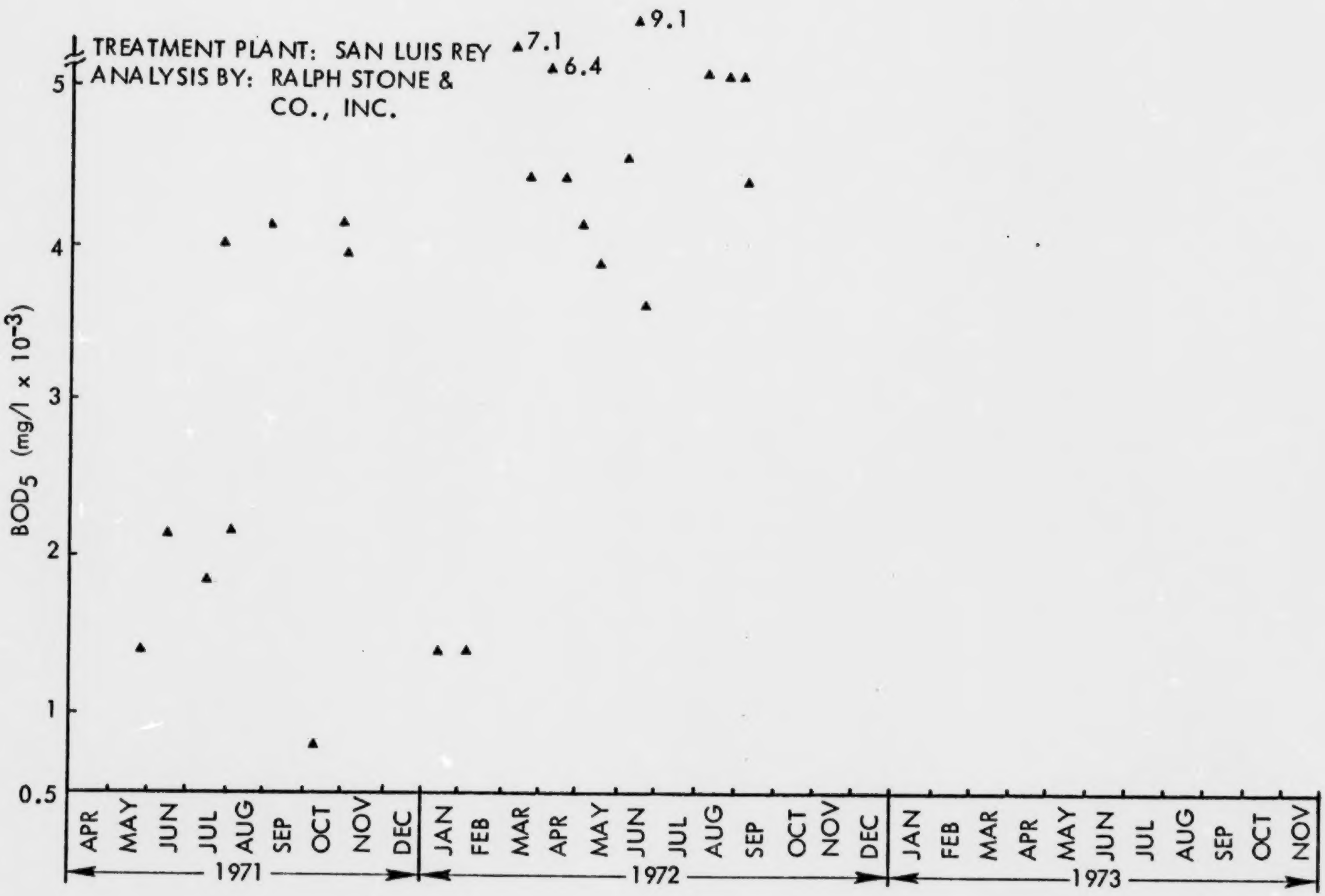
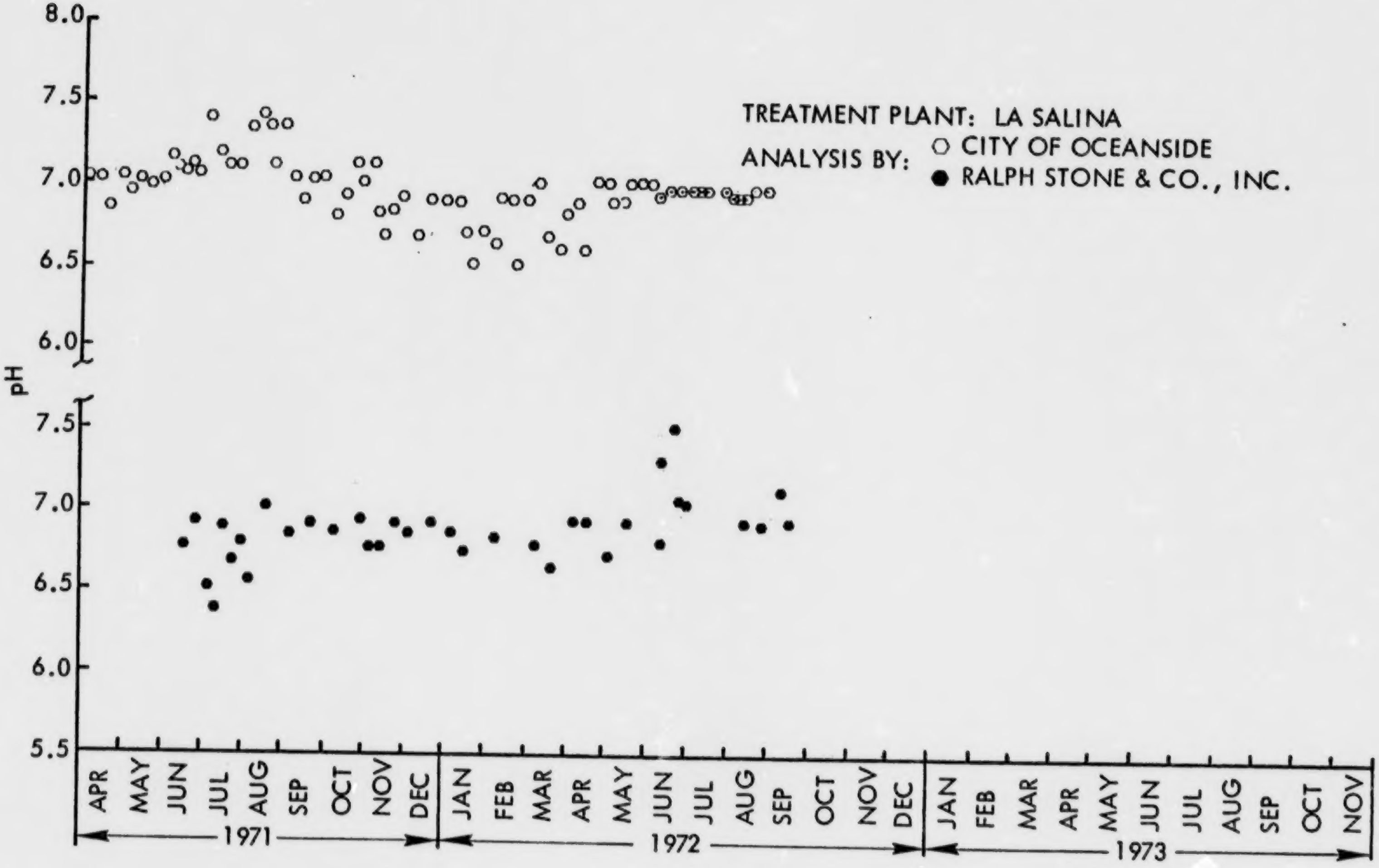


FIGURE C3
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



CITY OF OCEANSIDE/E.P.A.

FIGURE C4
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

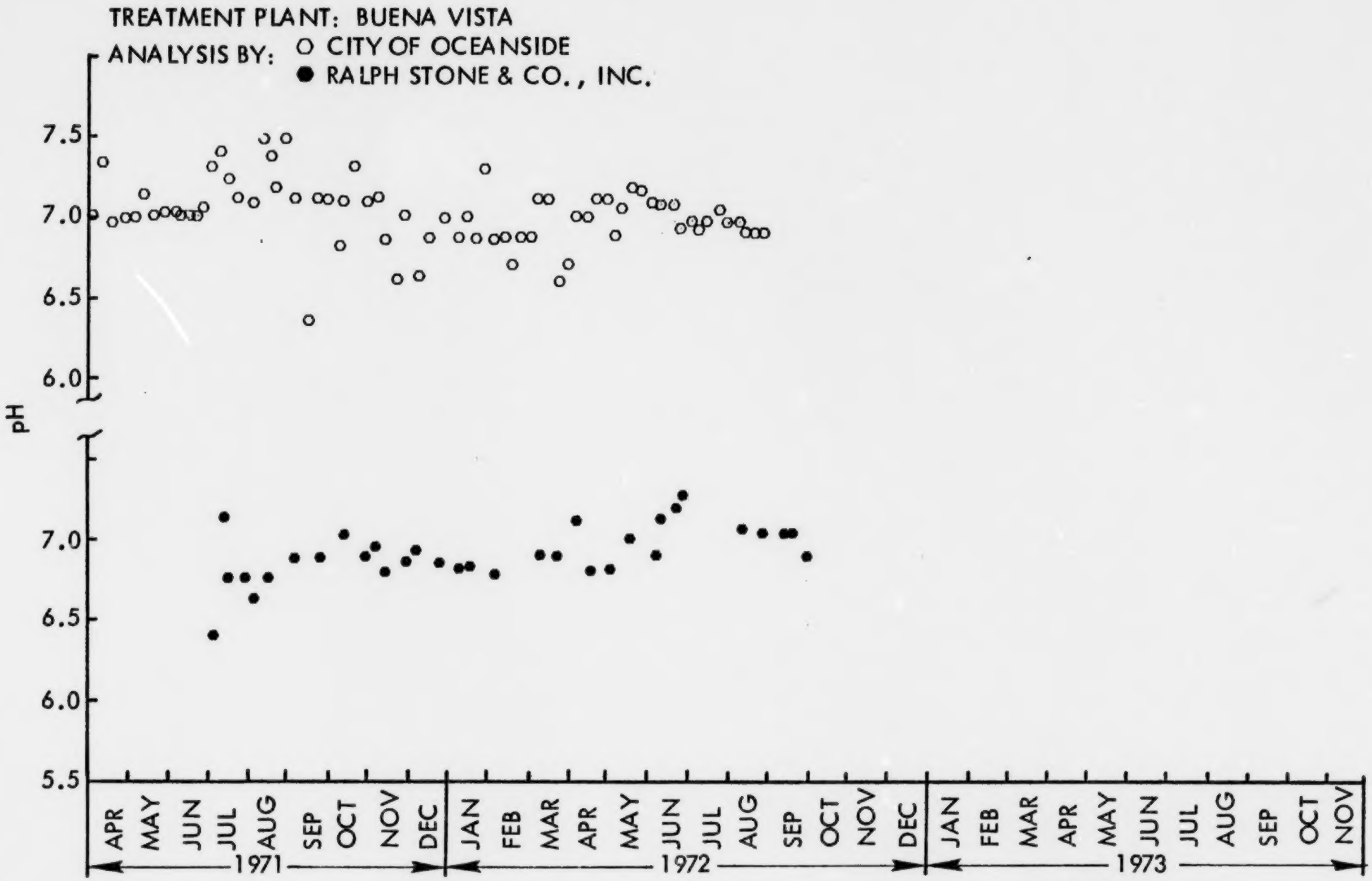
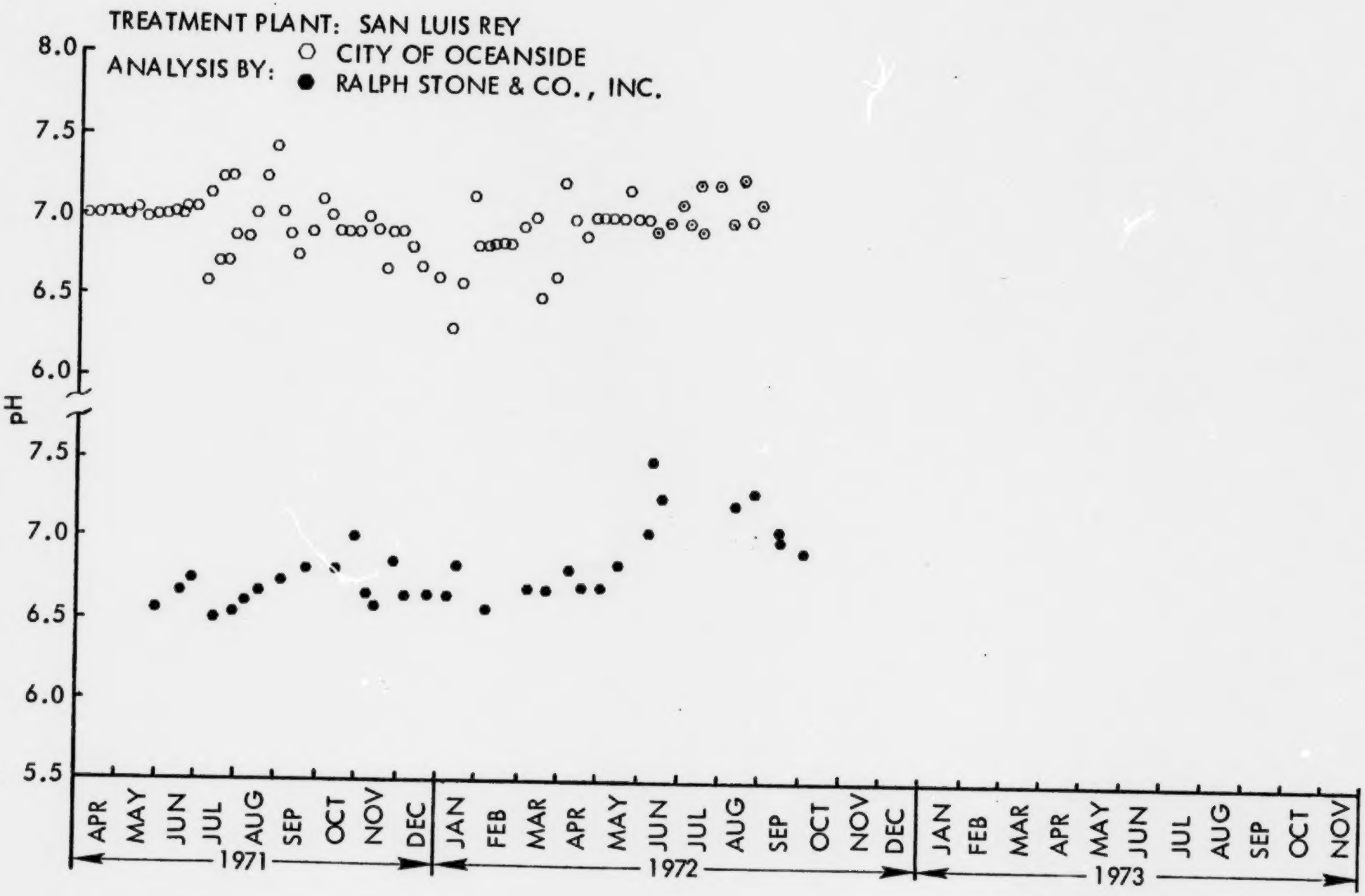
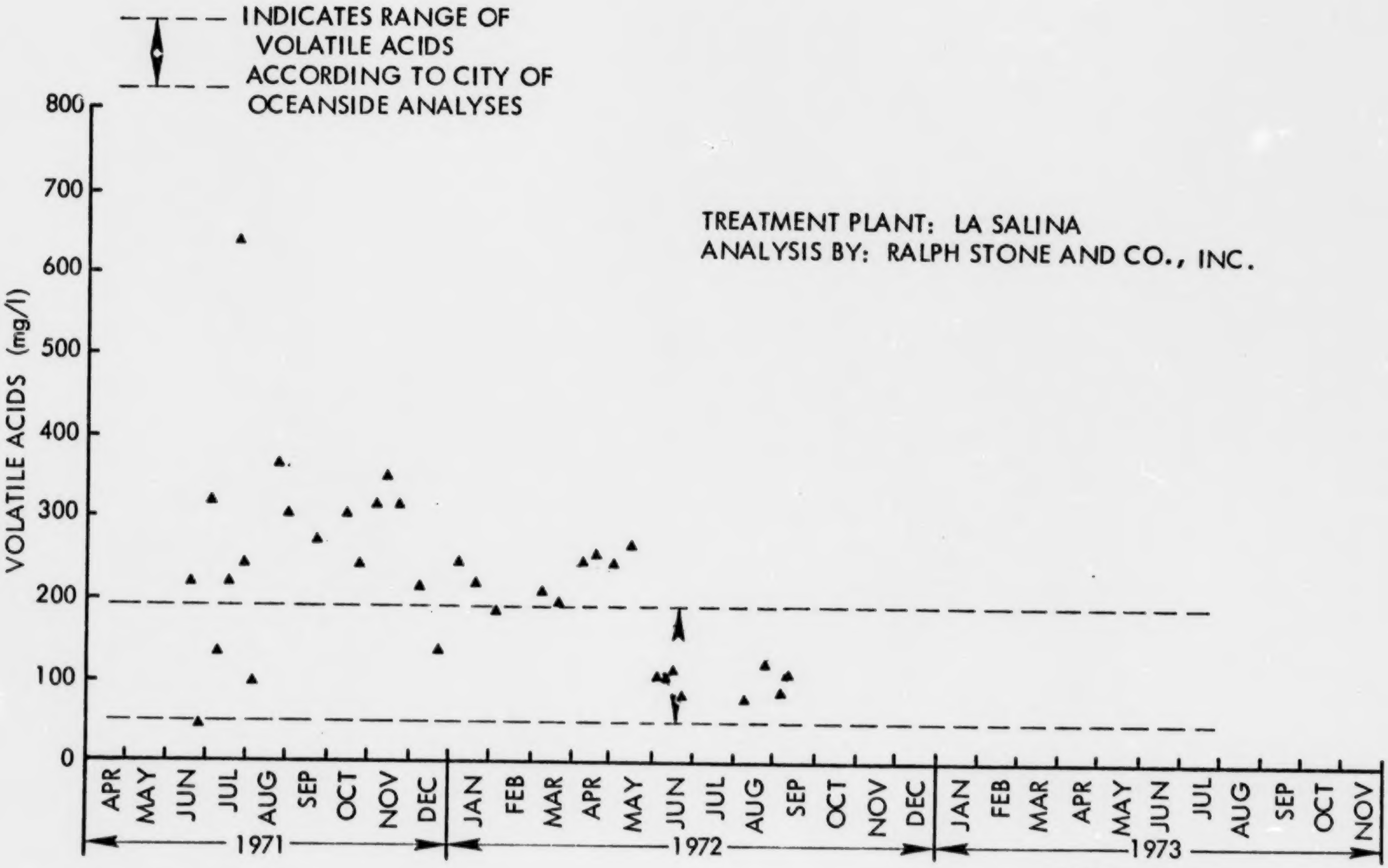


FIGURE C5
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



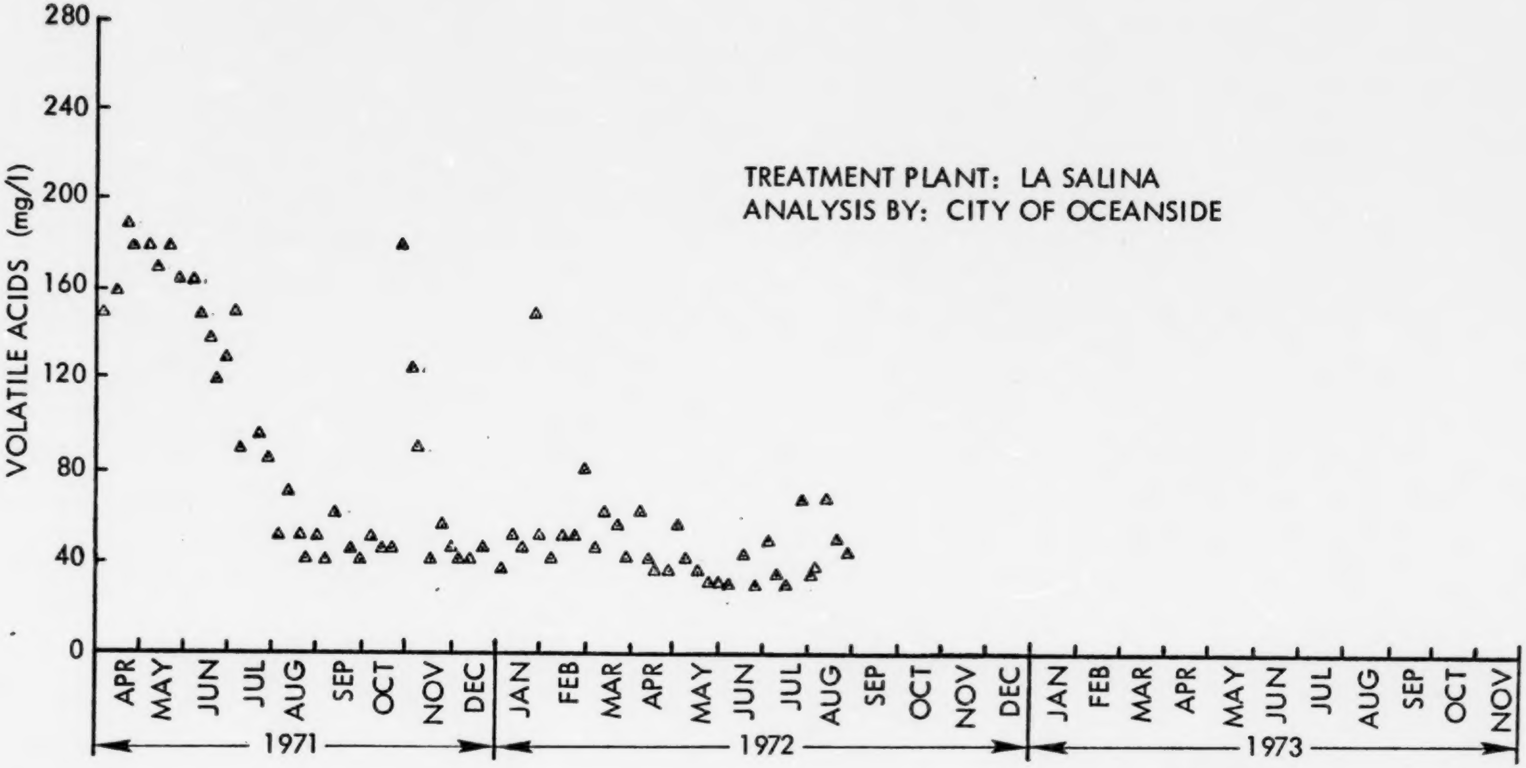
CITY OF OCEANSIDE/E.P.A.

FIGURE C6
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



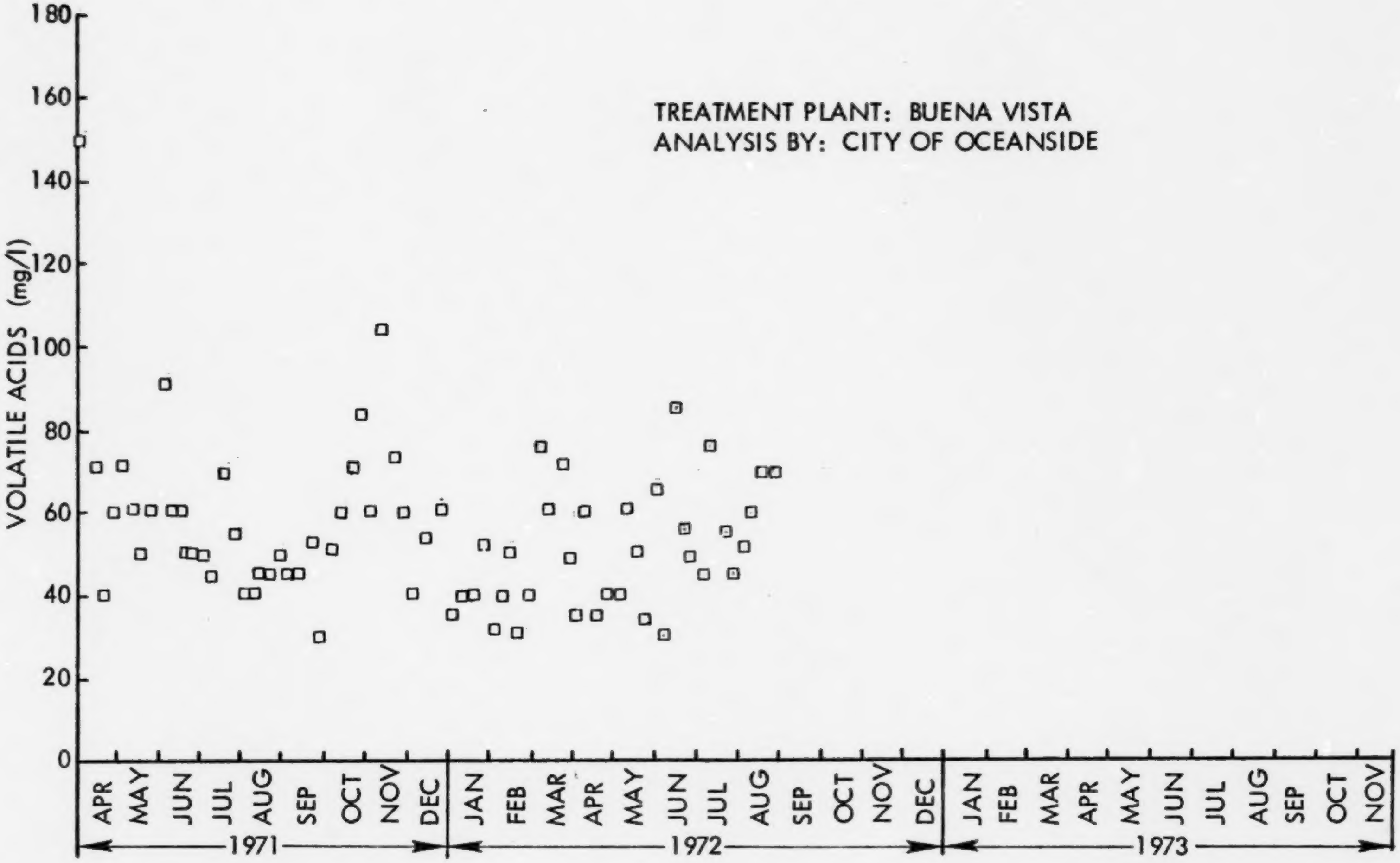
CITY OF OCEANSIDE/E.P.A.

FIGURE C7
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



CITY OF OCEANSIDE/E.P.A.

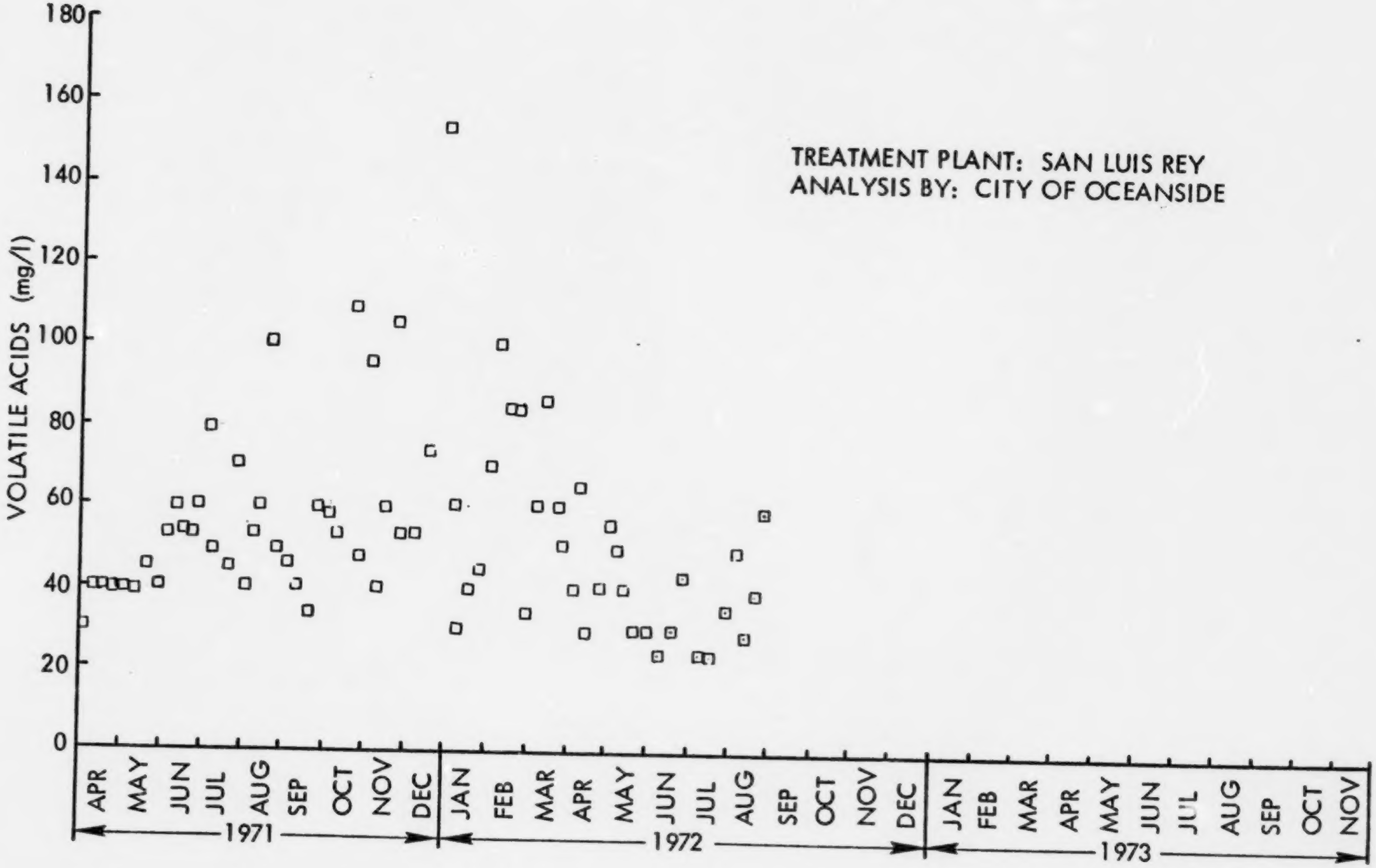
FIGURE C8
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



TREATMENT PLANT: BUENA VISTA
ANALYSIS BY: CITY OF OCEANSIDE

CITY OF OCEANSIDE/E.P.A.

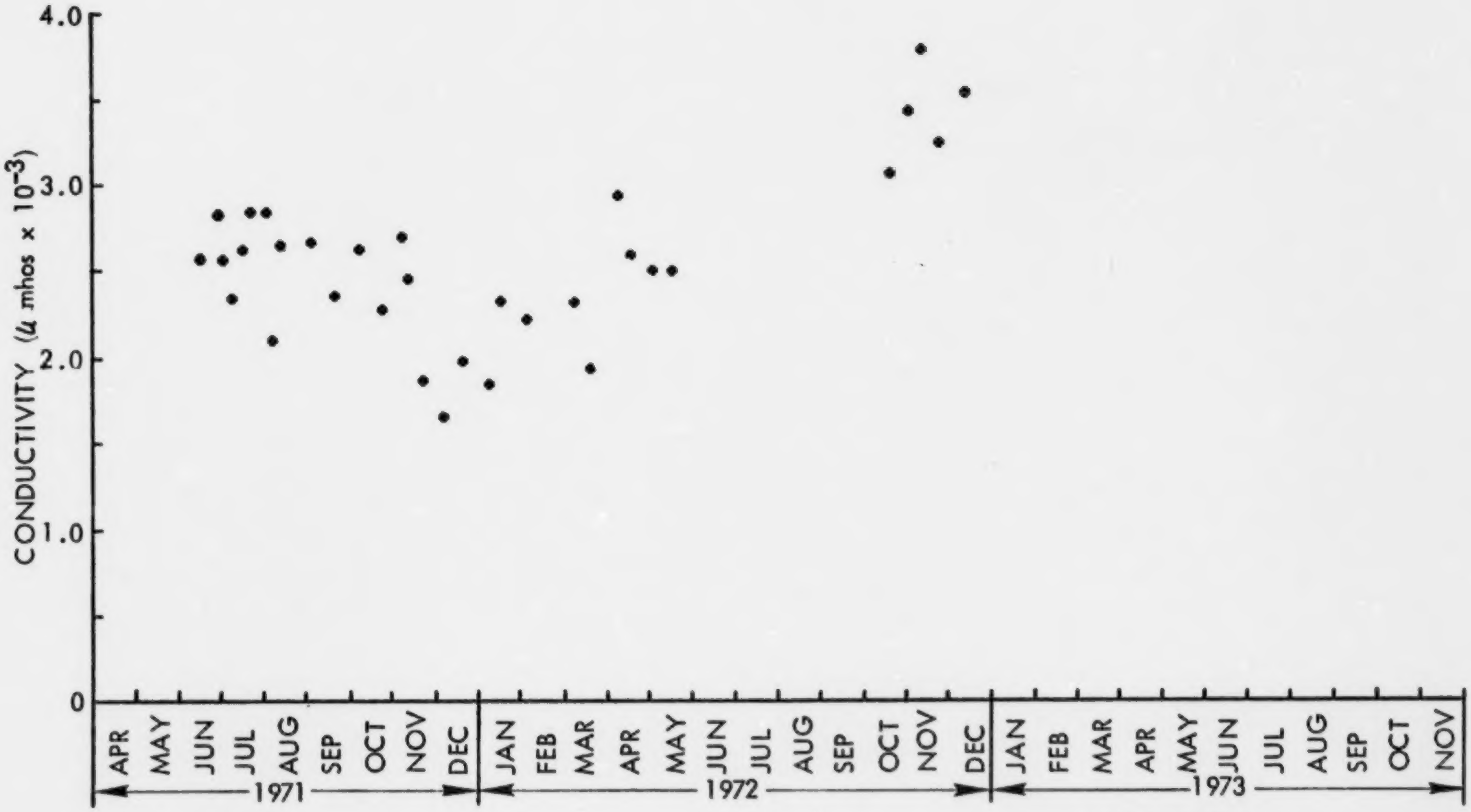
FIGURE C9
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



CITY OF OCEANSIDE/E.P.A.

FIGURE C10
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

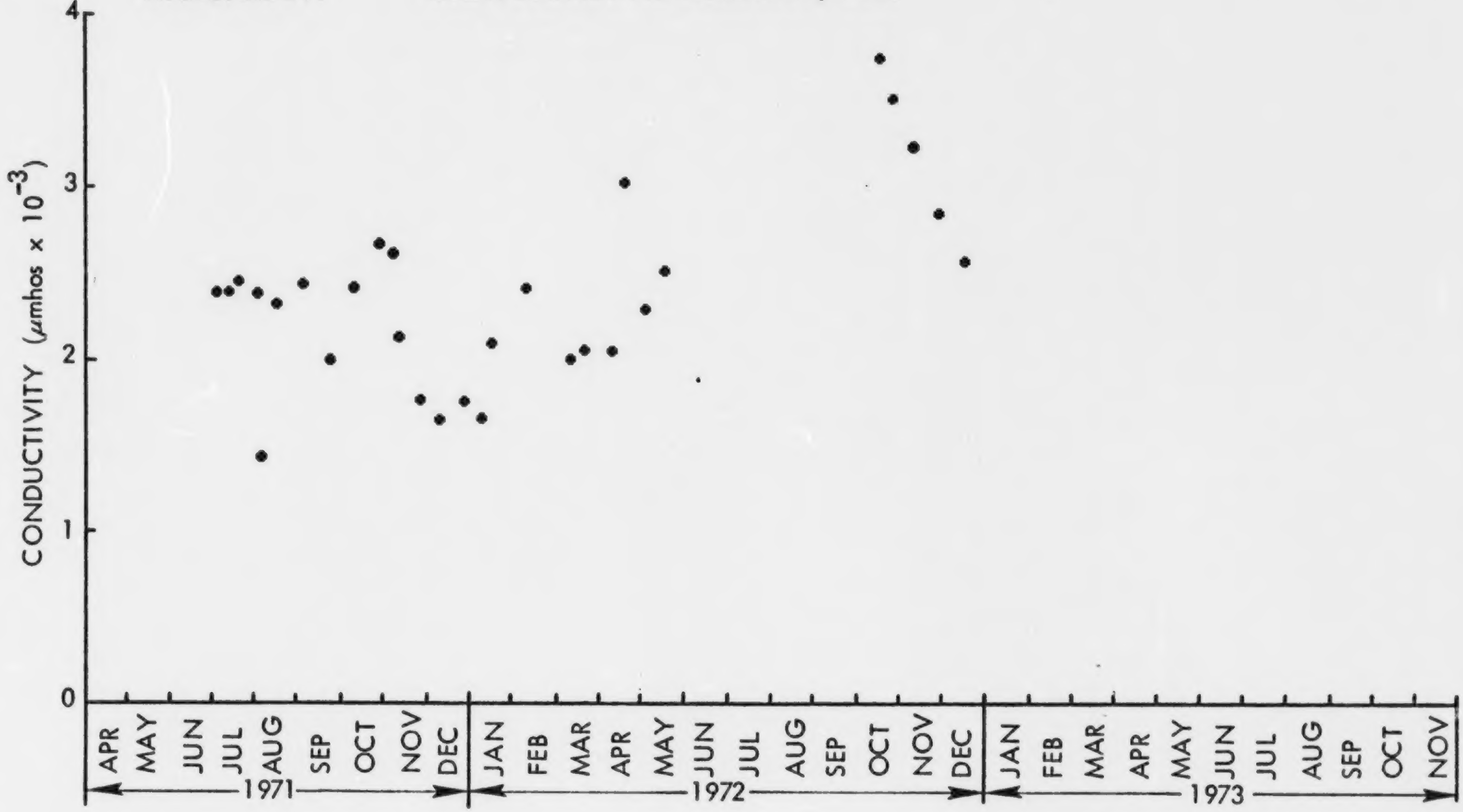
TREATMENT PLANT: LA SALINA
ANALYSIS BY: RALPH STONE AND COMPANY, INC.



CITY OF OCEANSIDE/E.P.A.

FIGURE C11
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

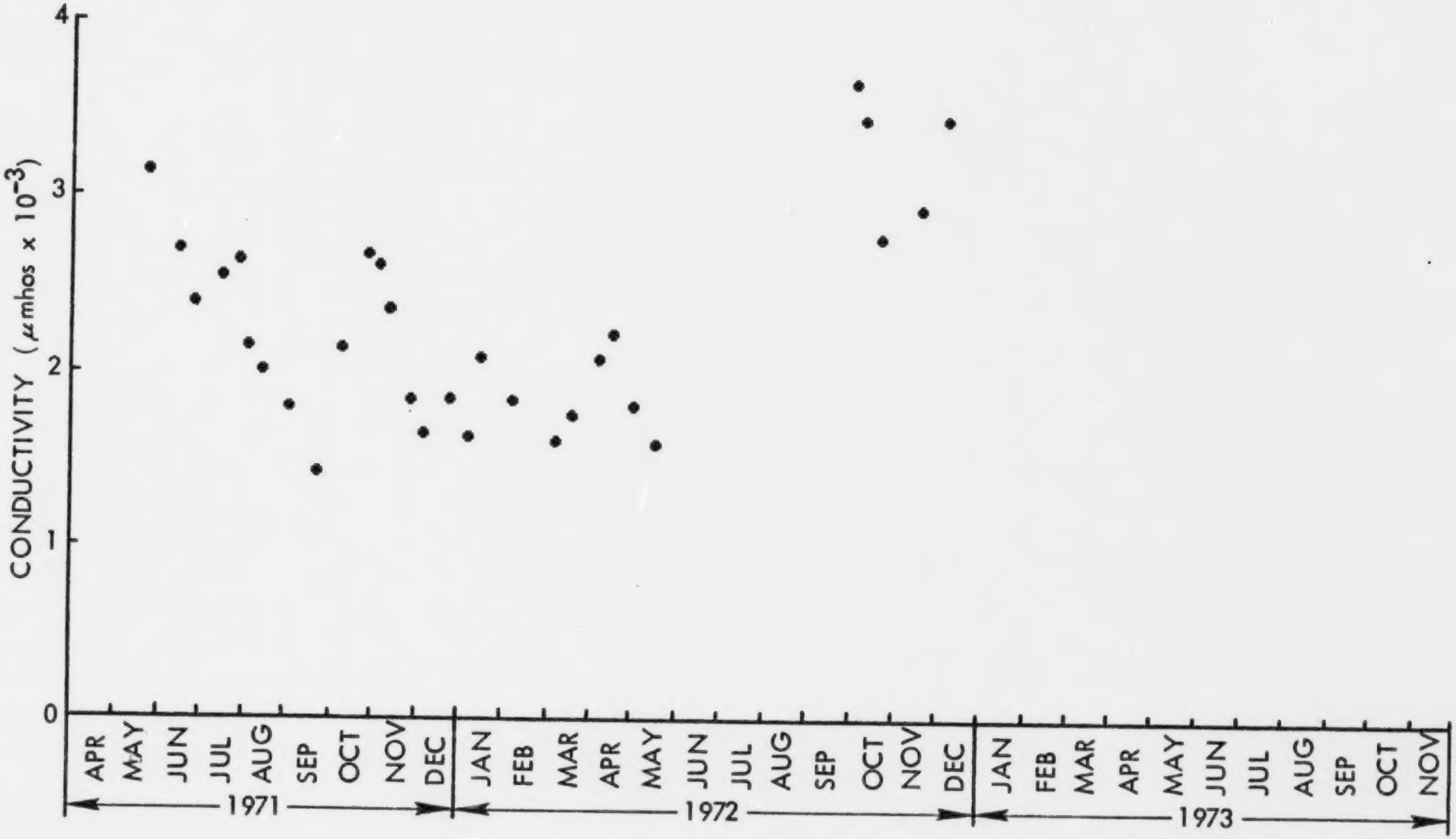
TREATMENT PLANT: BUENA VISTA
ANALYSIS BY: RALPH STONE AND COMPANY, INC.



CITY OF OCEANSIDE/E.P.A.

FIGURE C12
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

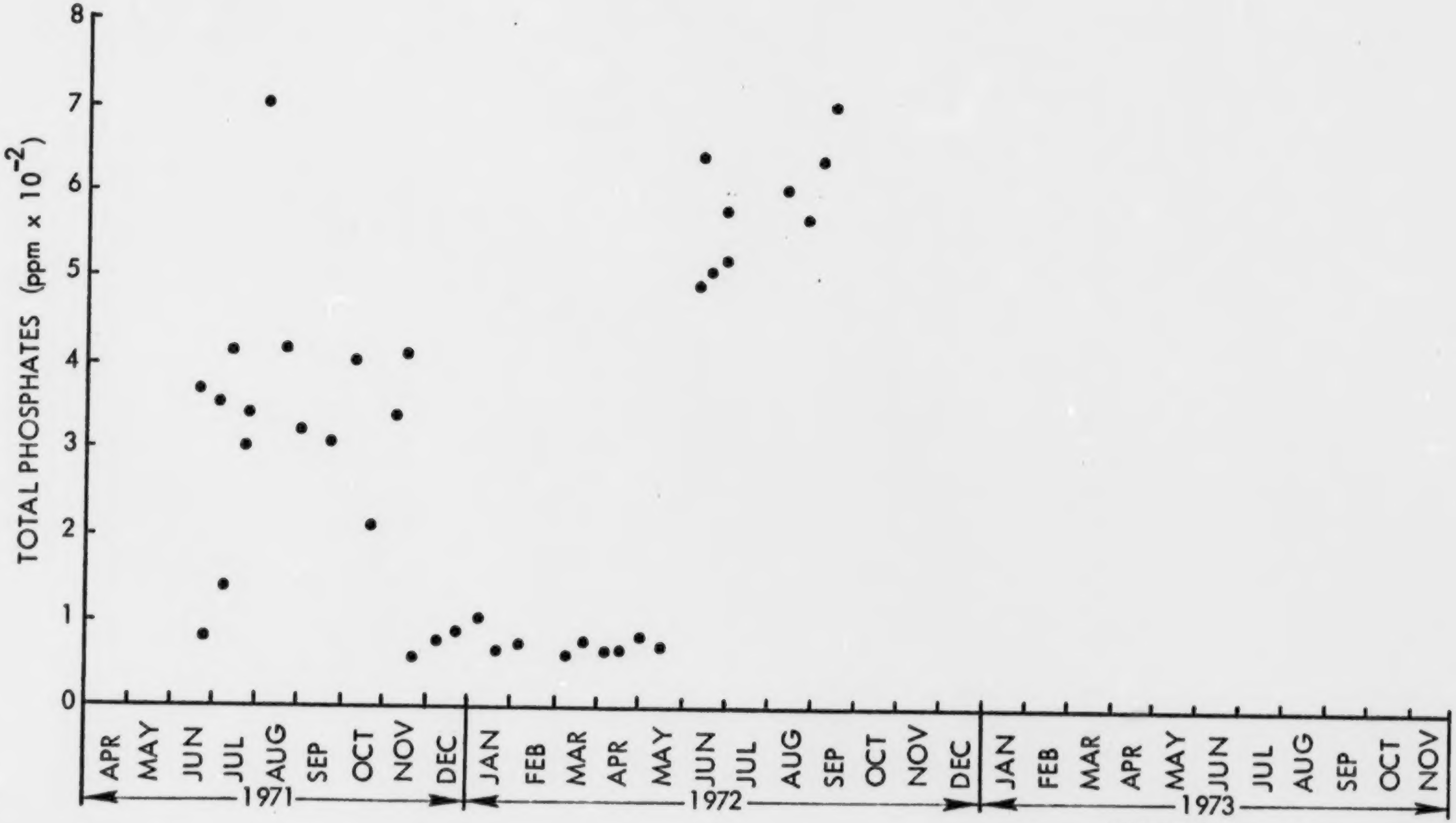
TREATMENT PLANT: SAN LUIS REY
ANALYSIS BY: RALPH STONE AND COMPANY, INC.



CITY OF OCEANSIDE/E.P.A.

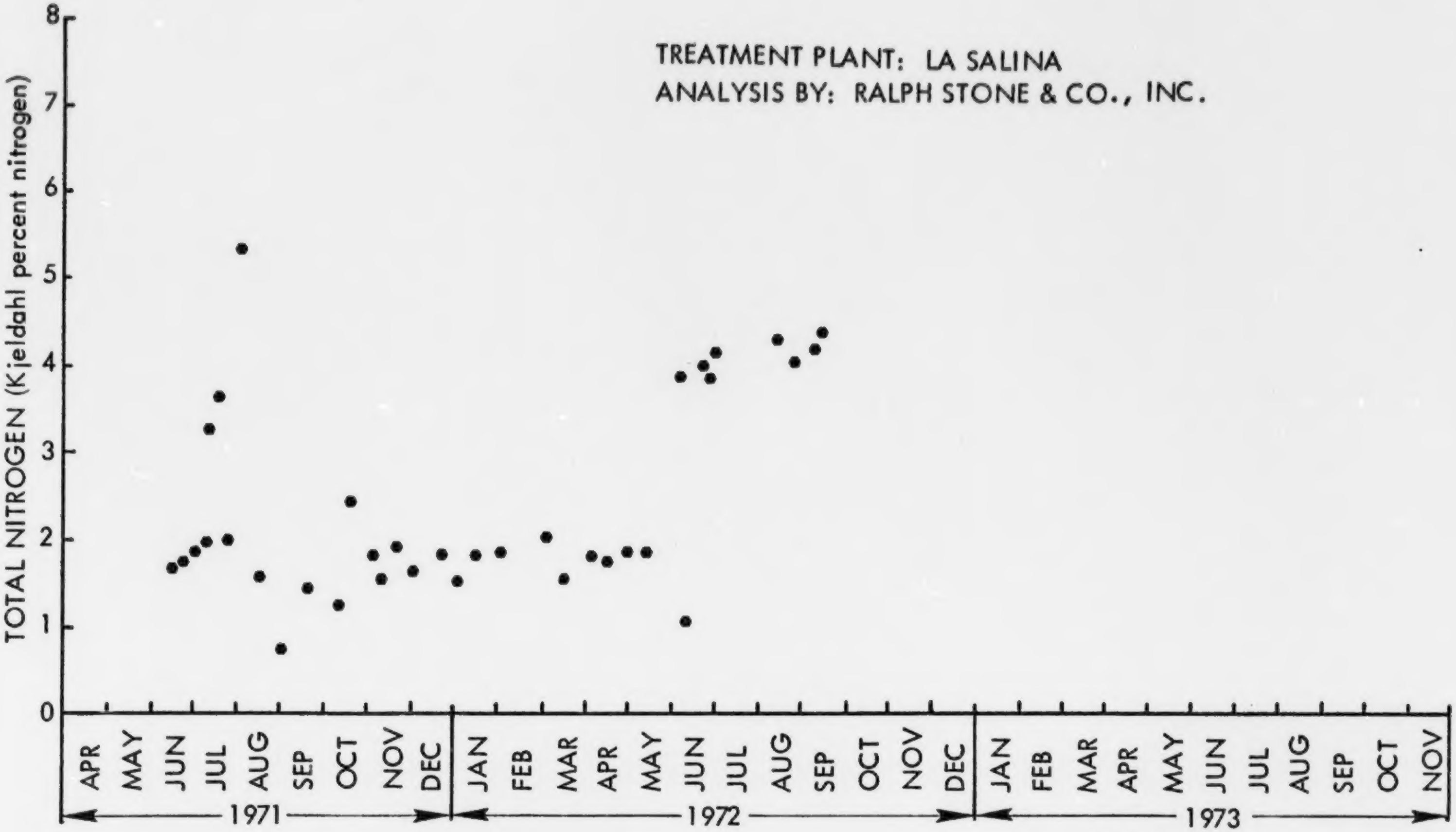
FIGURE C13
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

TREATMENT PLANT: LA SALINA
ANALYSIS BY: RALPH STONE & CO., INC.



CITY OF OCEANSIDE/E.P.A.

FIGURE C14
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA



TREATMENT PLANT: LA SALINA
ANALYSIS BY: RALPH STONE & CO., INC.

CITY OF OCEANSIDE/E.P.A.

FIGURE C15
PROPERTIES OF SLUDGES
FROM OCEANSIDE, CALIFORNIA

APPENDIX D

LABORATORY ANALYSIS OF LEACHATES FROM PILOT SCALE TEST DRUMS

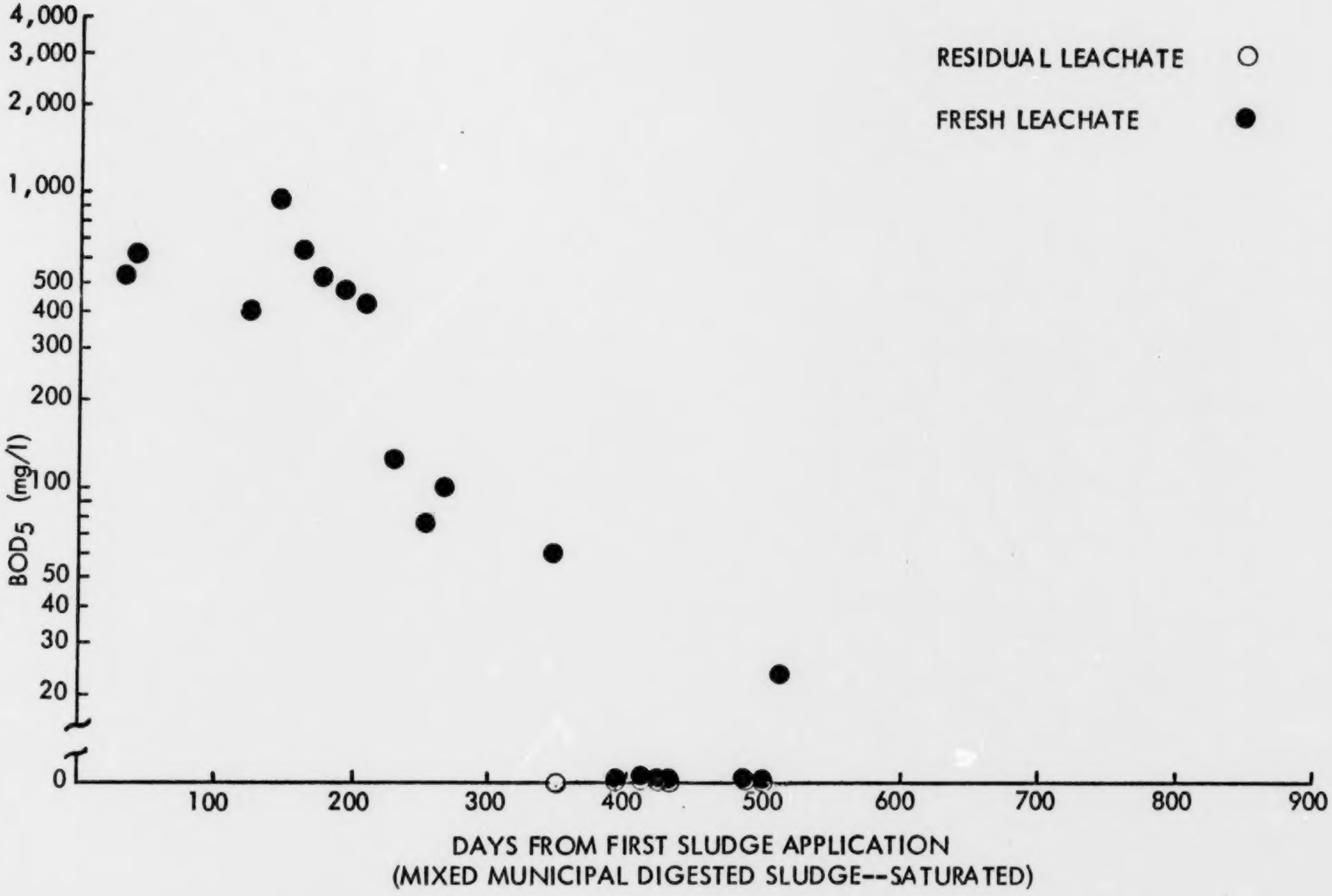
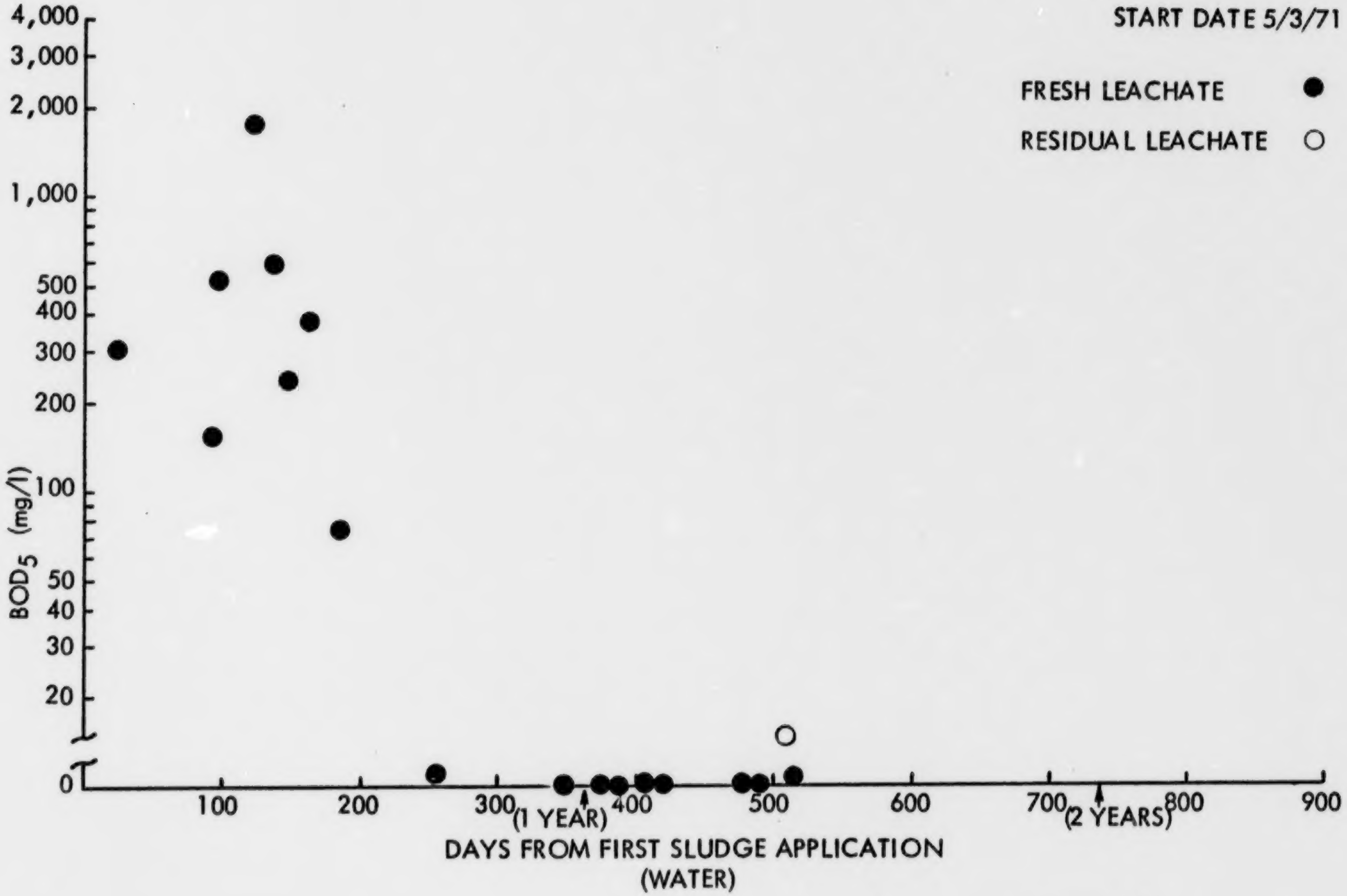


FIGURE D1
LEACHATE BOD_5 VS. TIME
DRUM NO. 1

CITY OF OCEANSIDE/E.P.A.



CITY OF OCEANSIDE/E.P.A.

FIGURE D2
LEACHATE BOD_5 VS. TIME
DRUM NO. 2

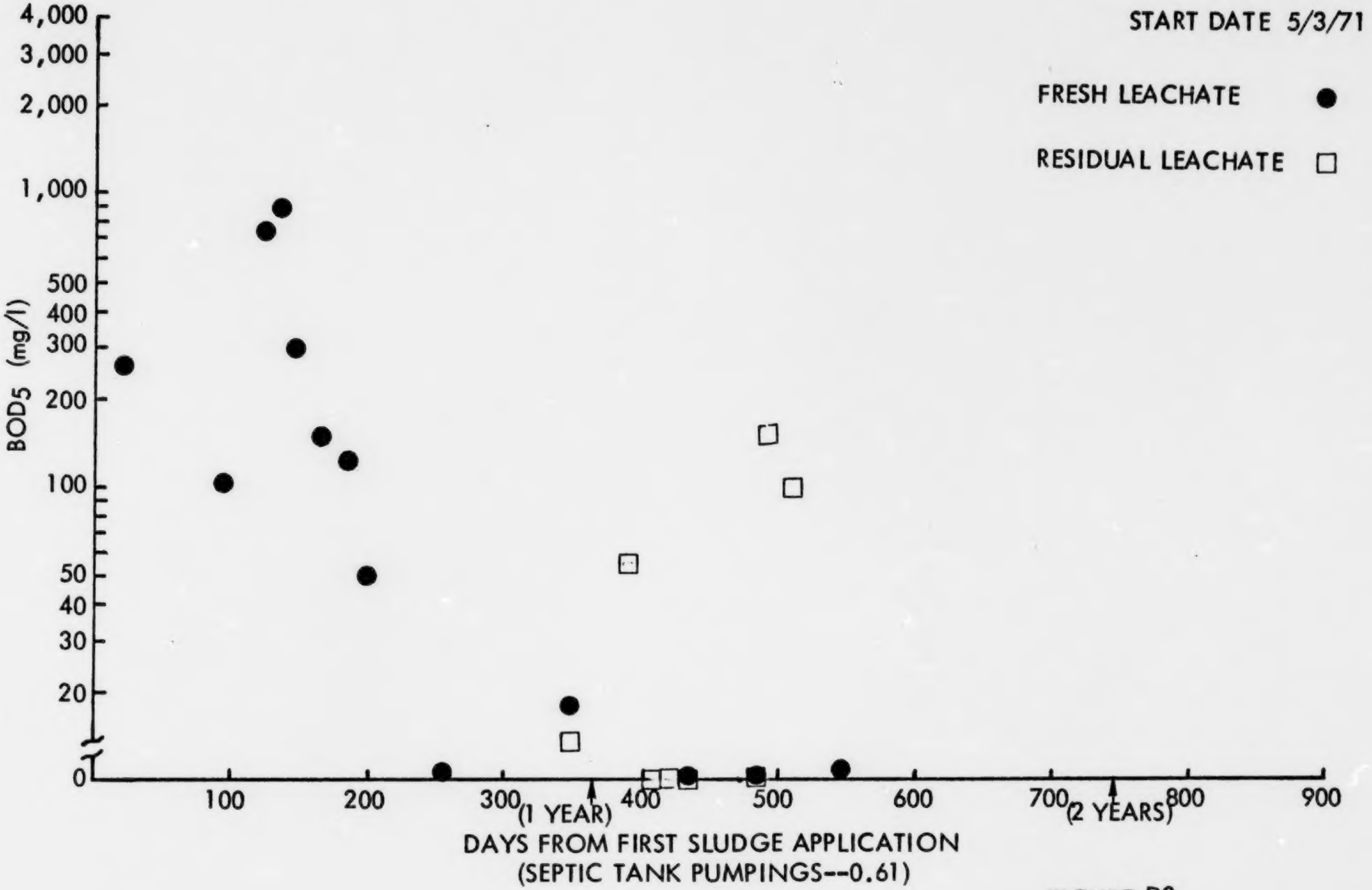
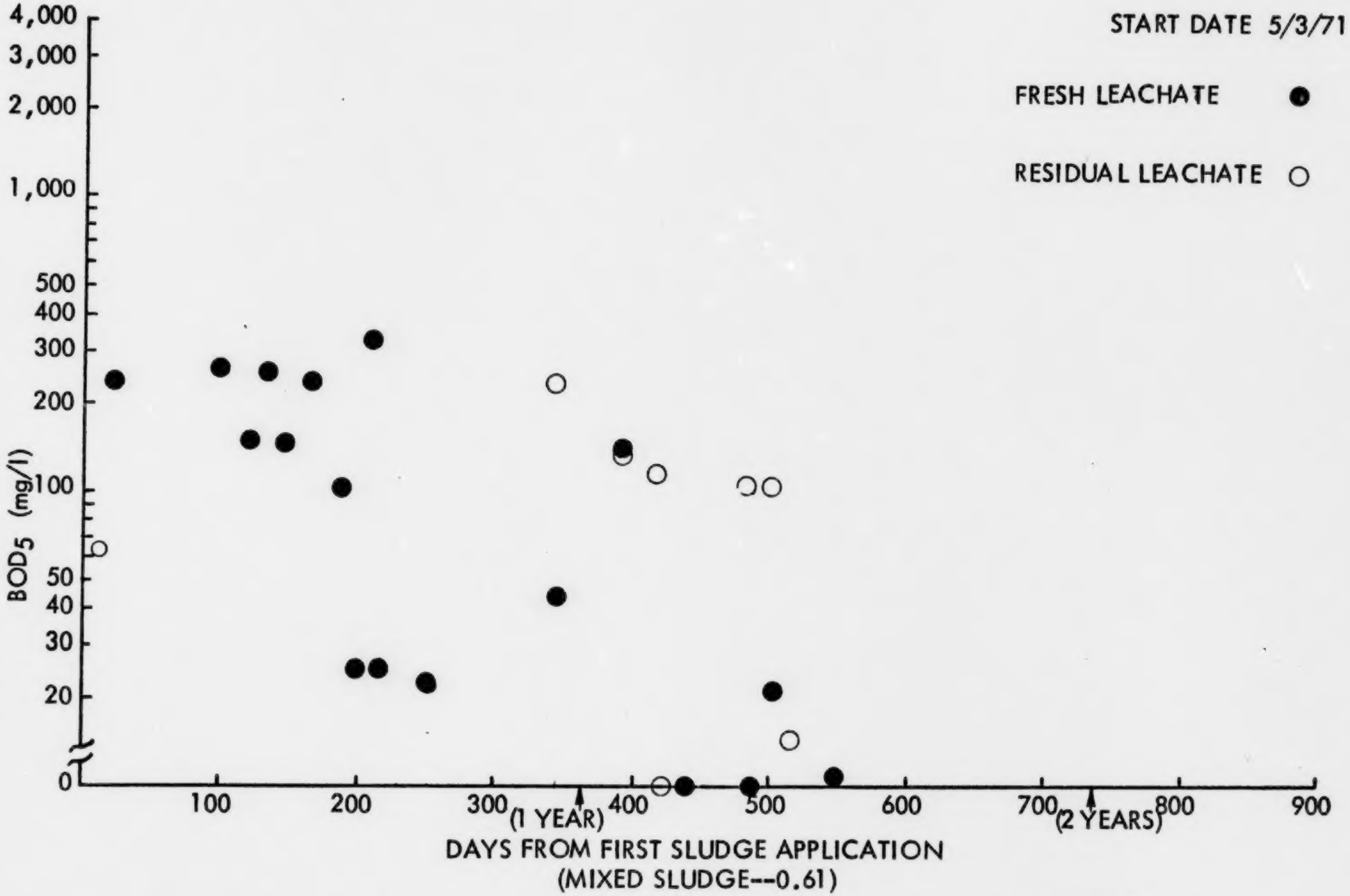
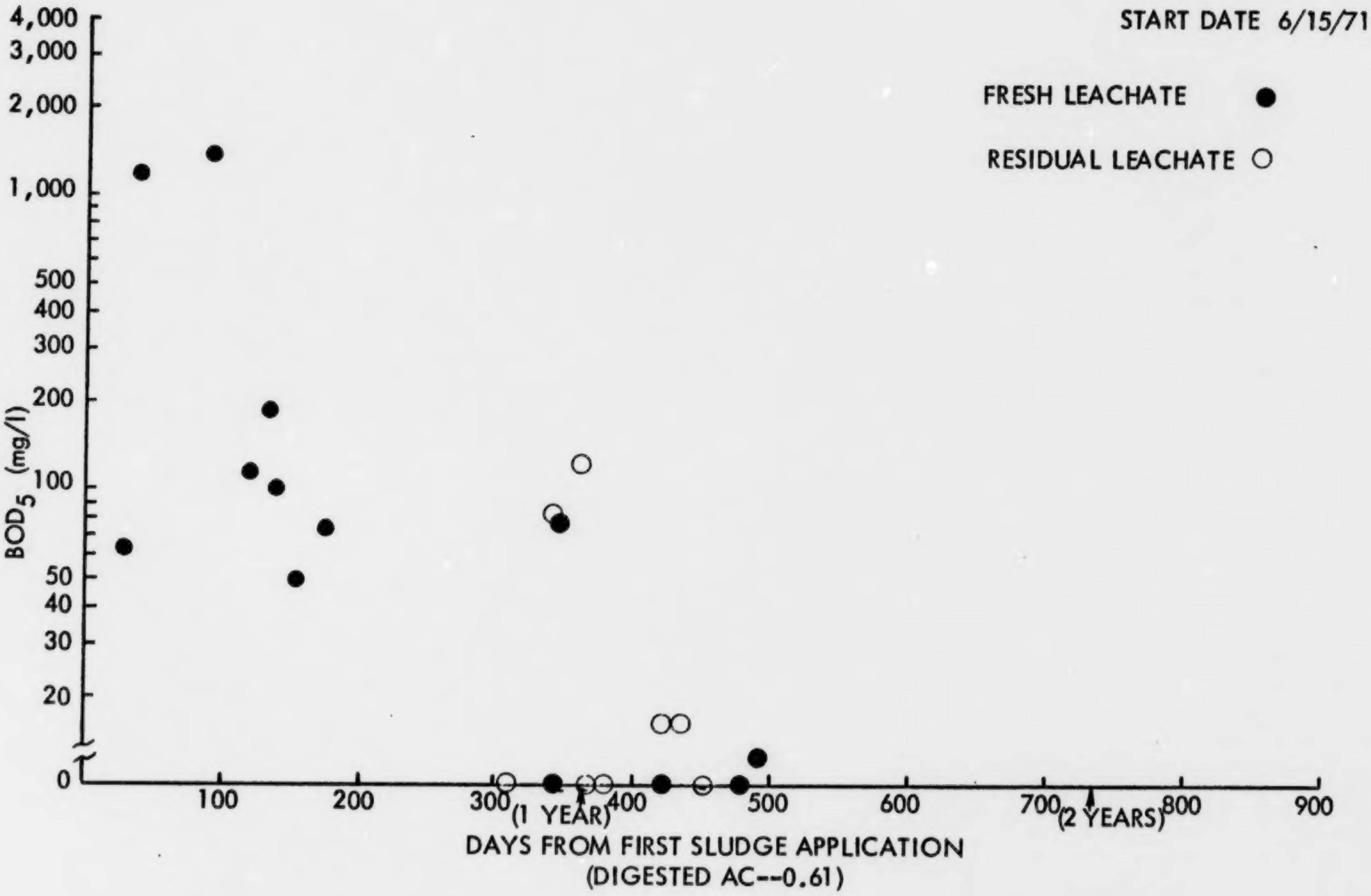


FIGURE D3
LEACHATE BOD_5 VS. TIME
DRUM NO. 3



CITY OF OCEANSIDE/E.P.A.

FIGURE D4
LEACHATE BOD_5 VS. TIME
DRUM NO. 5



CITY OF OCEANSIDE/E.P.A.

FIGURE D5
LEACHATE BOD_5 VS. TIME
DRUM NO. 6

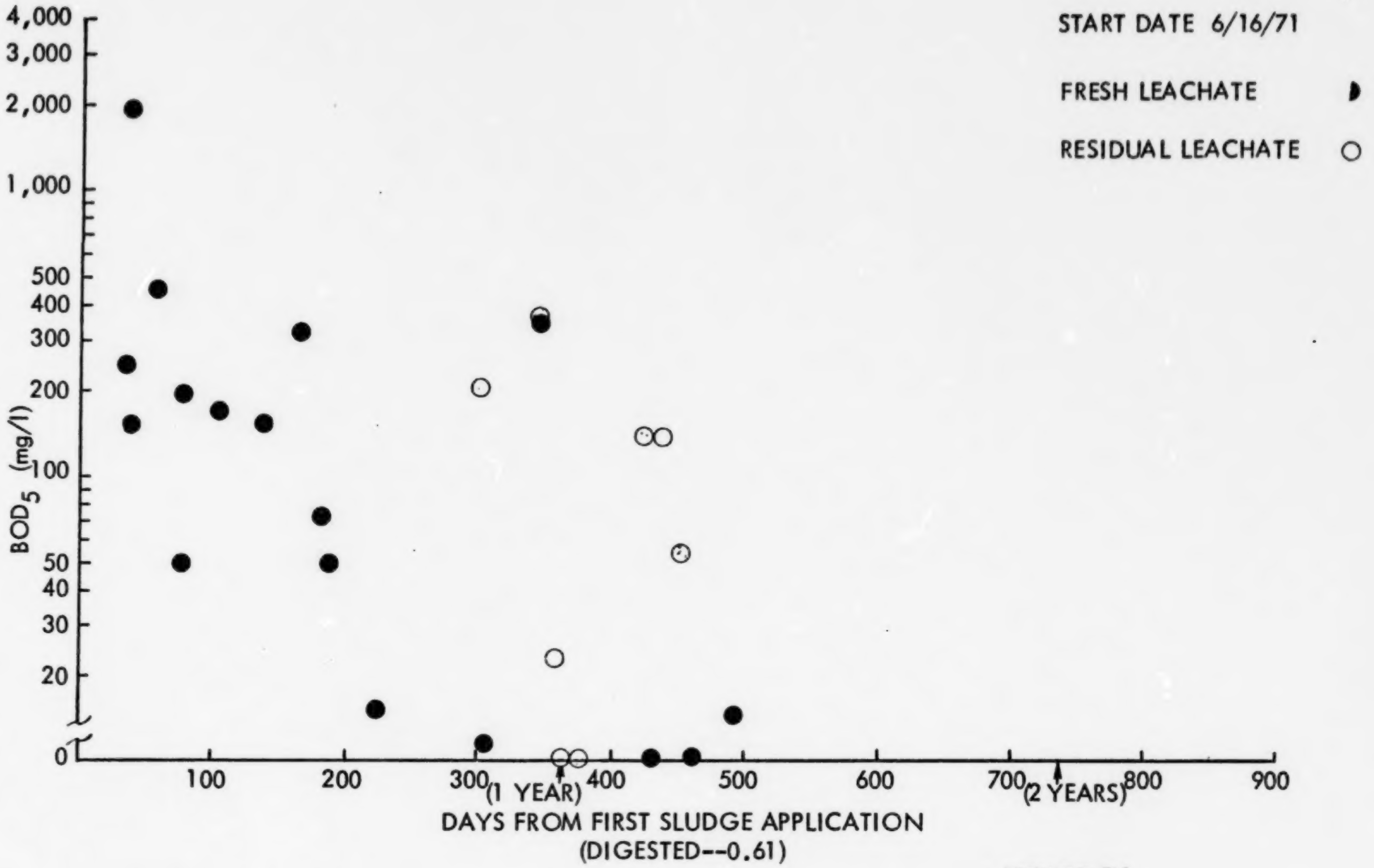


FIGURE D6
LEACHATE BOD_5 VS. TIME
DRUM NO. 7

CITY OF OCEANSIDE/E.P.A.

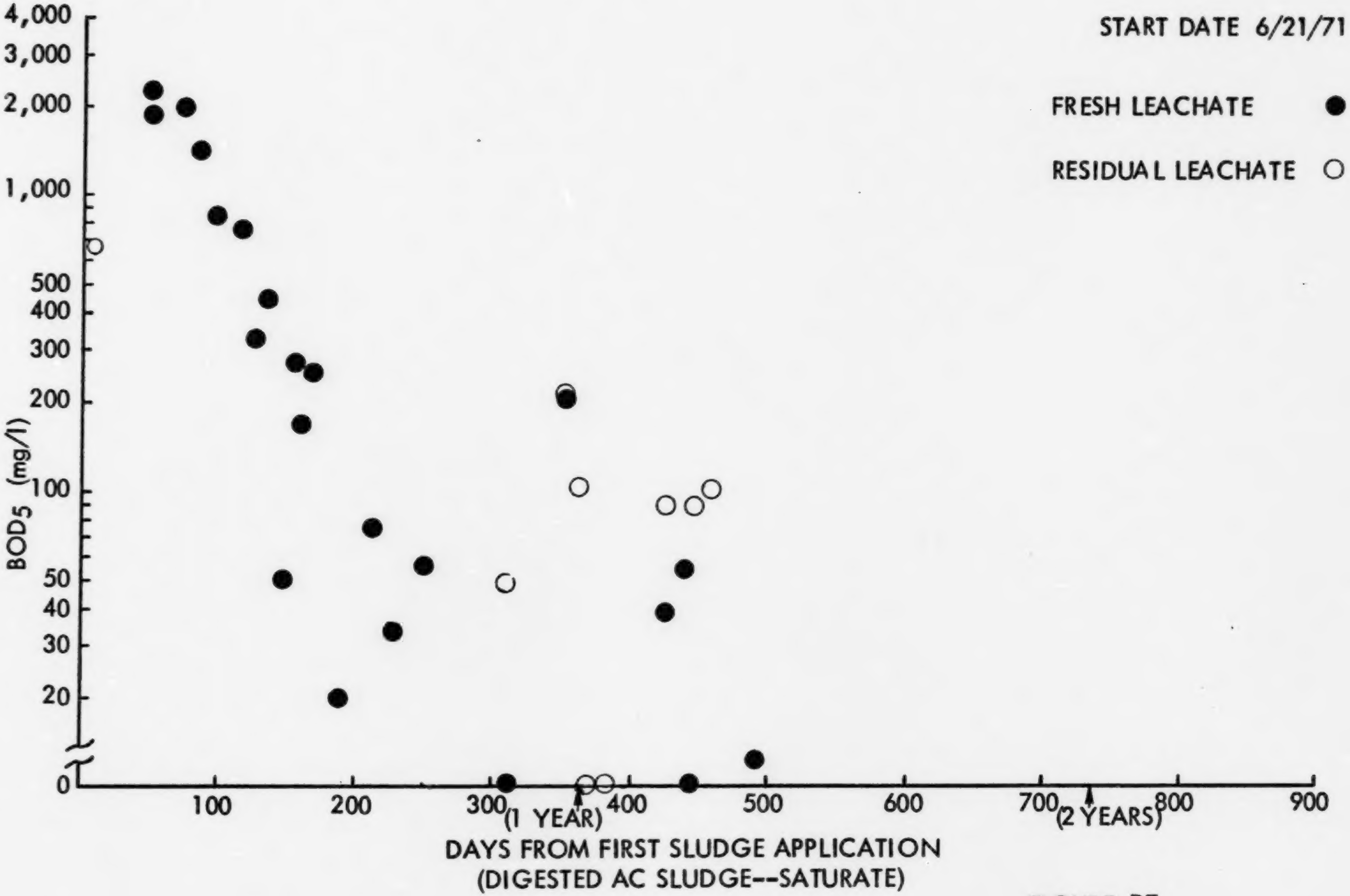
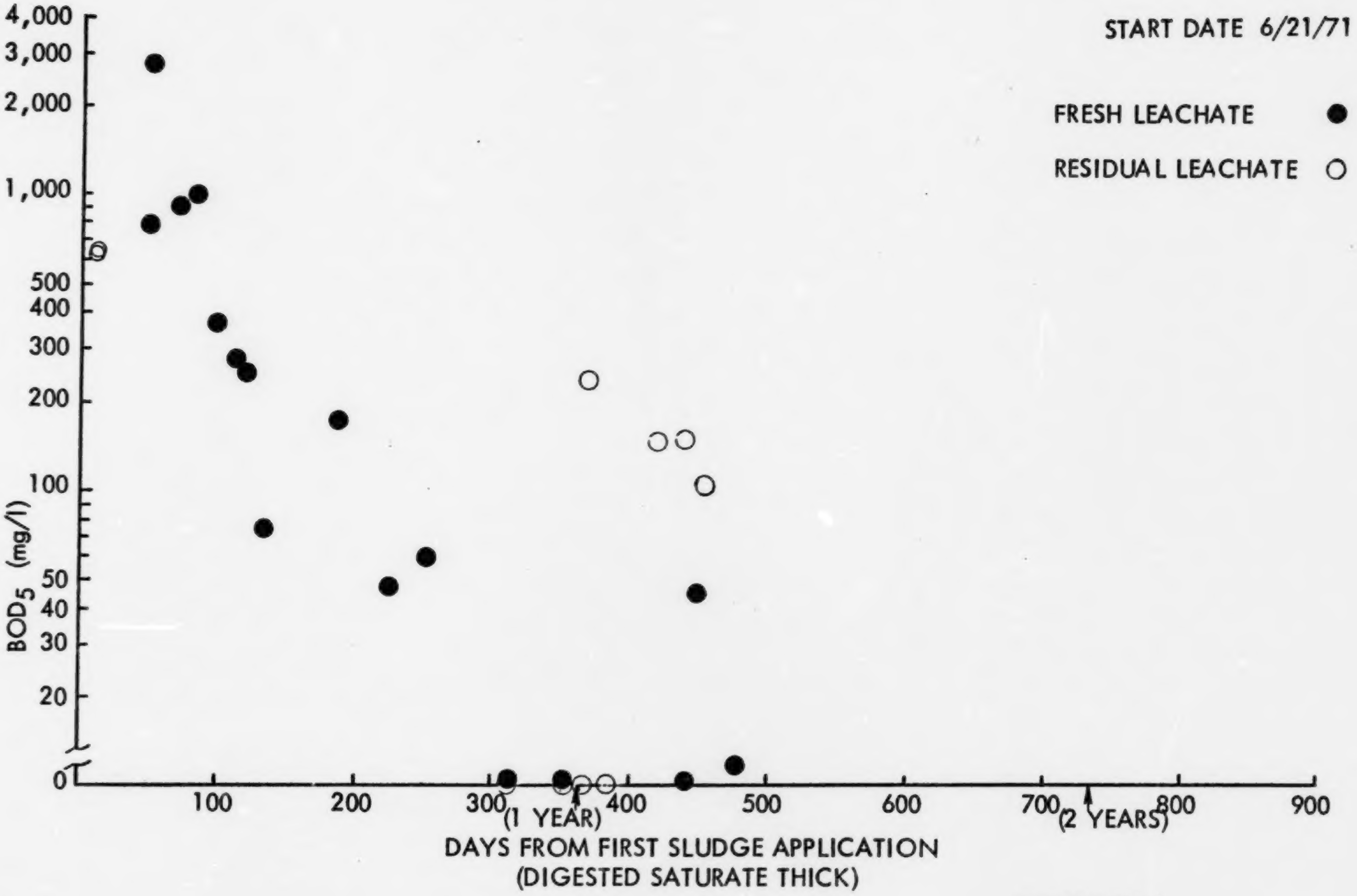


FIGURE D7
LEACHATE BOD_5 VS. TIME
DRUM NO. 8

CITY OF OCEANSIDE/E.P.A.



CITY OF OCEANSIDE/E.P.A.

FIGURE D8
LEACHATE BOD$_5$ VS. TIME
DRUM NO. 9

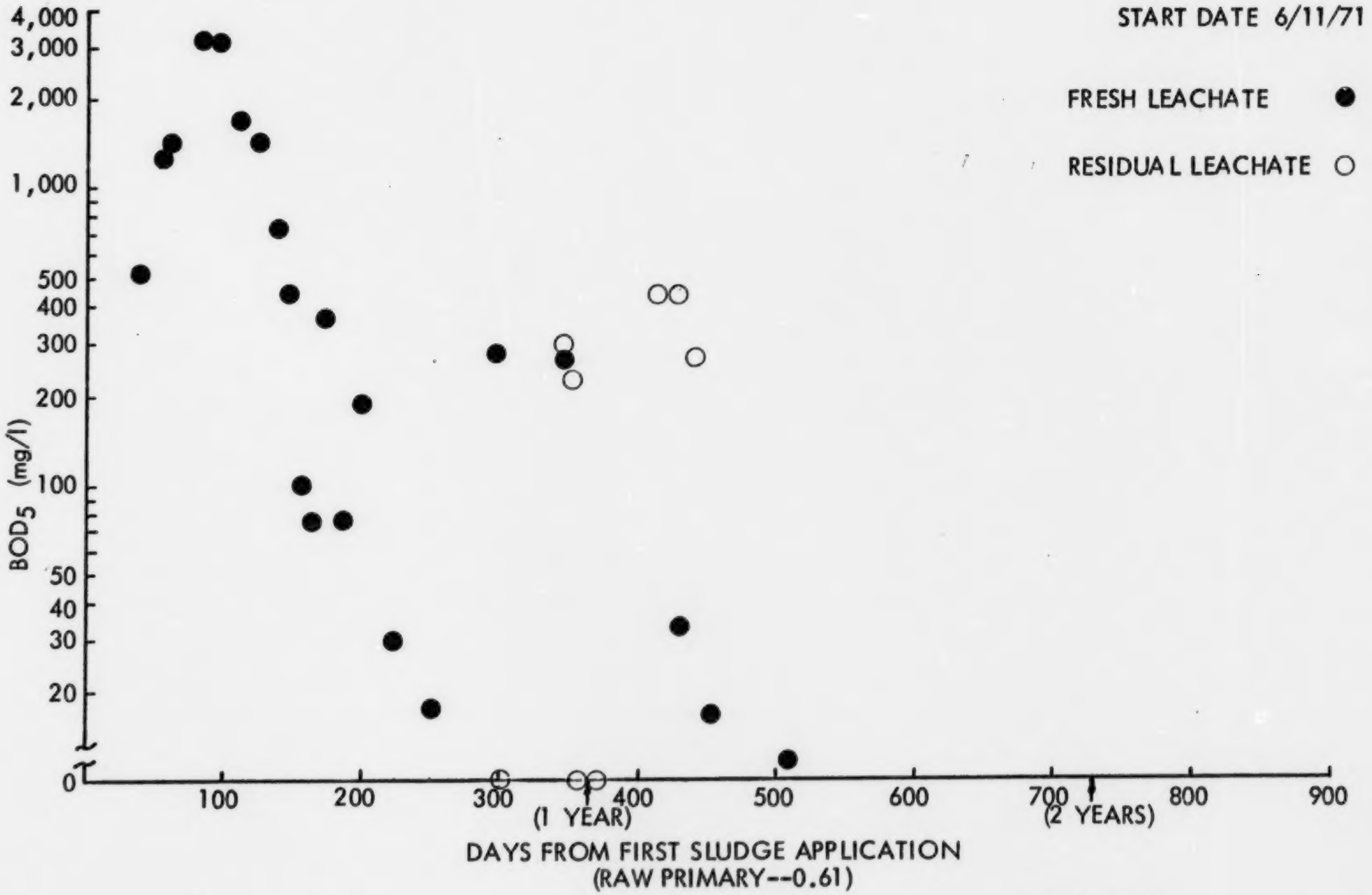


FIGURE D9
LEACHATE BOD5 VS. TIME
DRUM NO. 10

CITY OF OCEANSIDE/E.P.A.

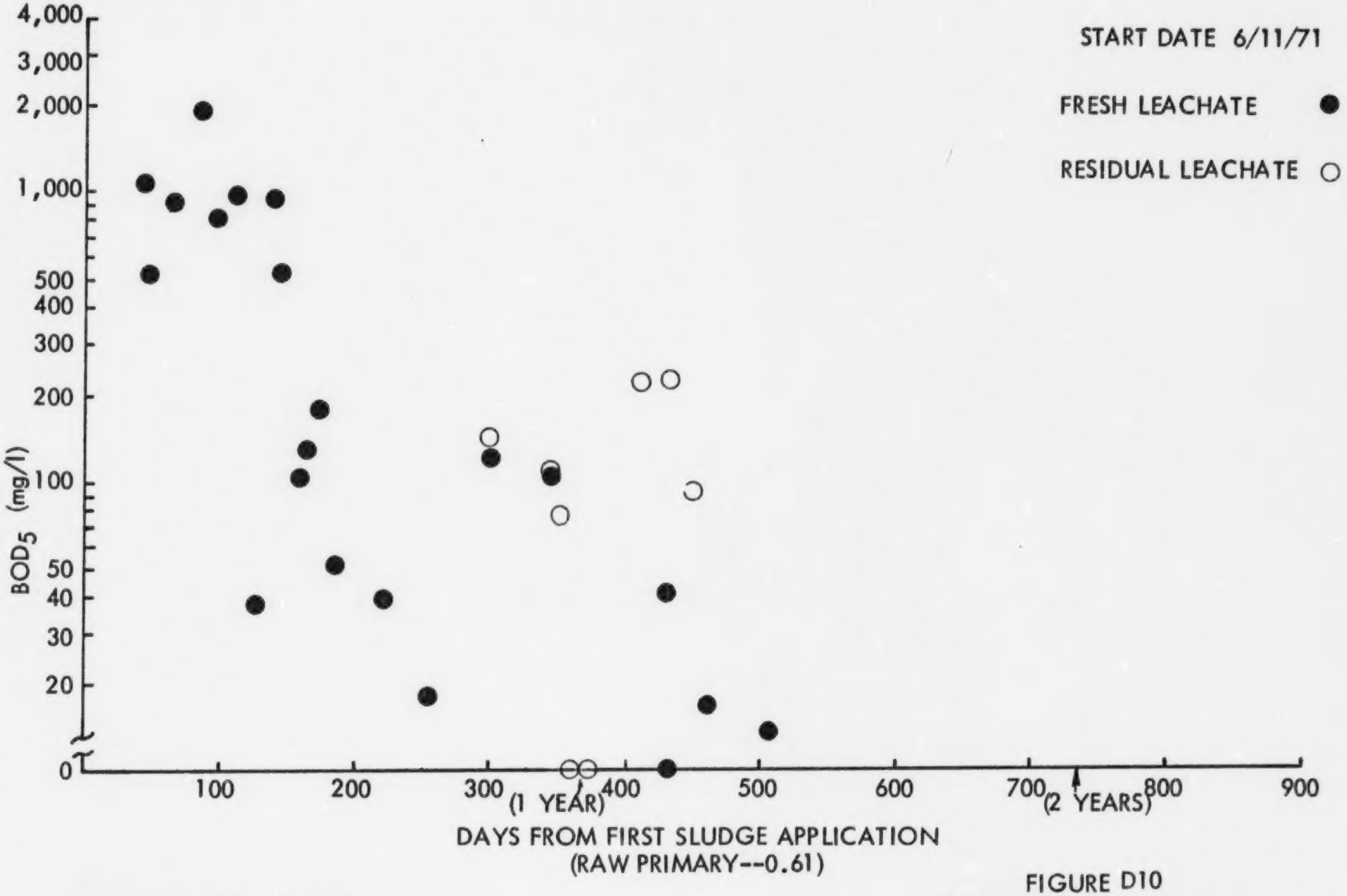


FIGURE D10
LEACHATE BOD$_5$ VS. TIME
DRUM NO. 11

CITY OF OCEANSIDE/E.P.A.

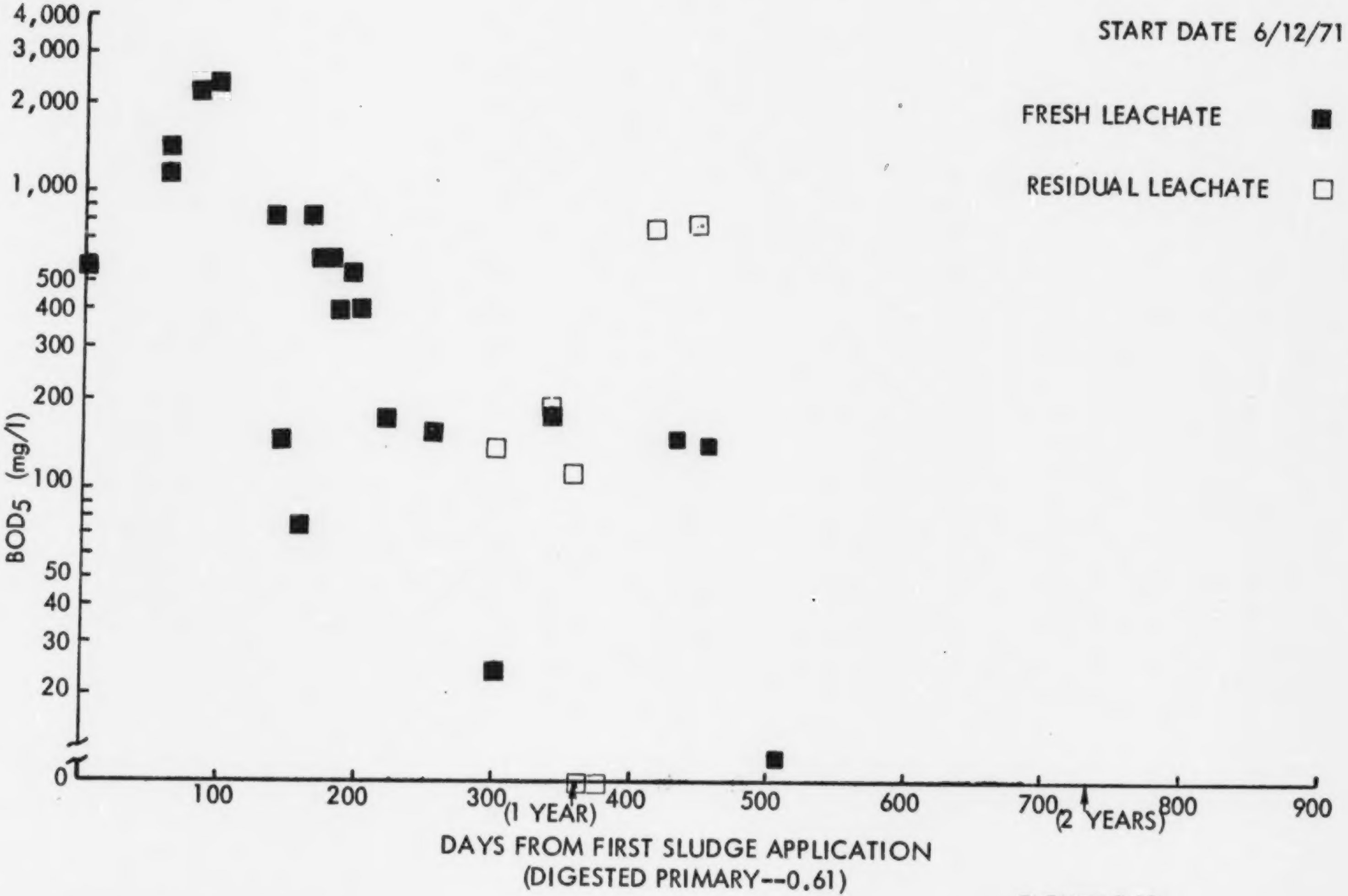
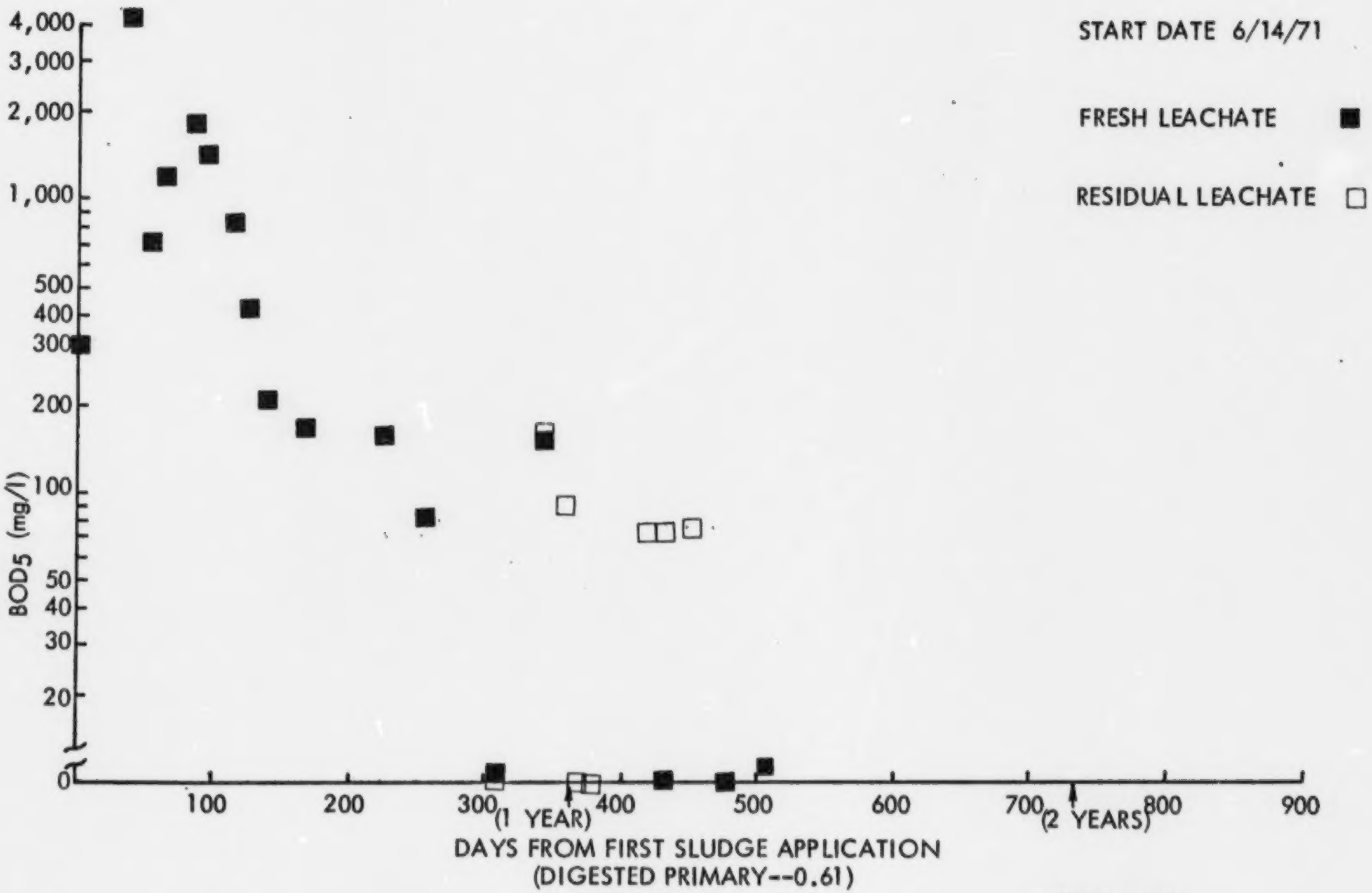
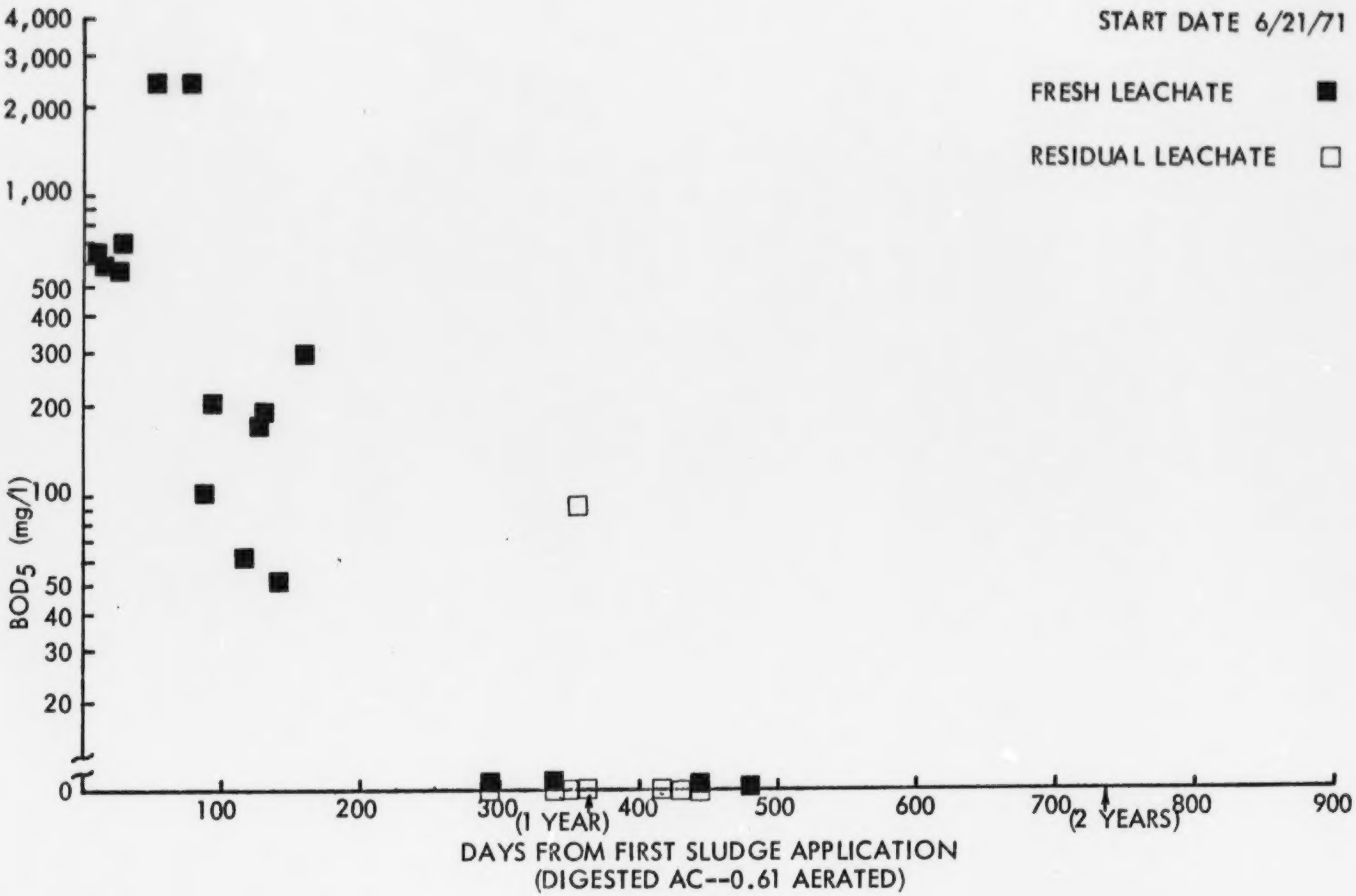


FIGURE D11
LEACHATE BOD_5 VS. TIME
DRUM NO. 12



CITY OF OCEANSIDE/E.P.A.

FIGURE D12
LEACHATE BOD_5 VS. TIME
DRUM NO. 13



CITY OF OCEANSIDE/E.P.A.

FIGURE D13
LEACHATE BOD_5 VS. TIME
DRUM NO. 14

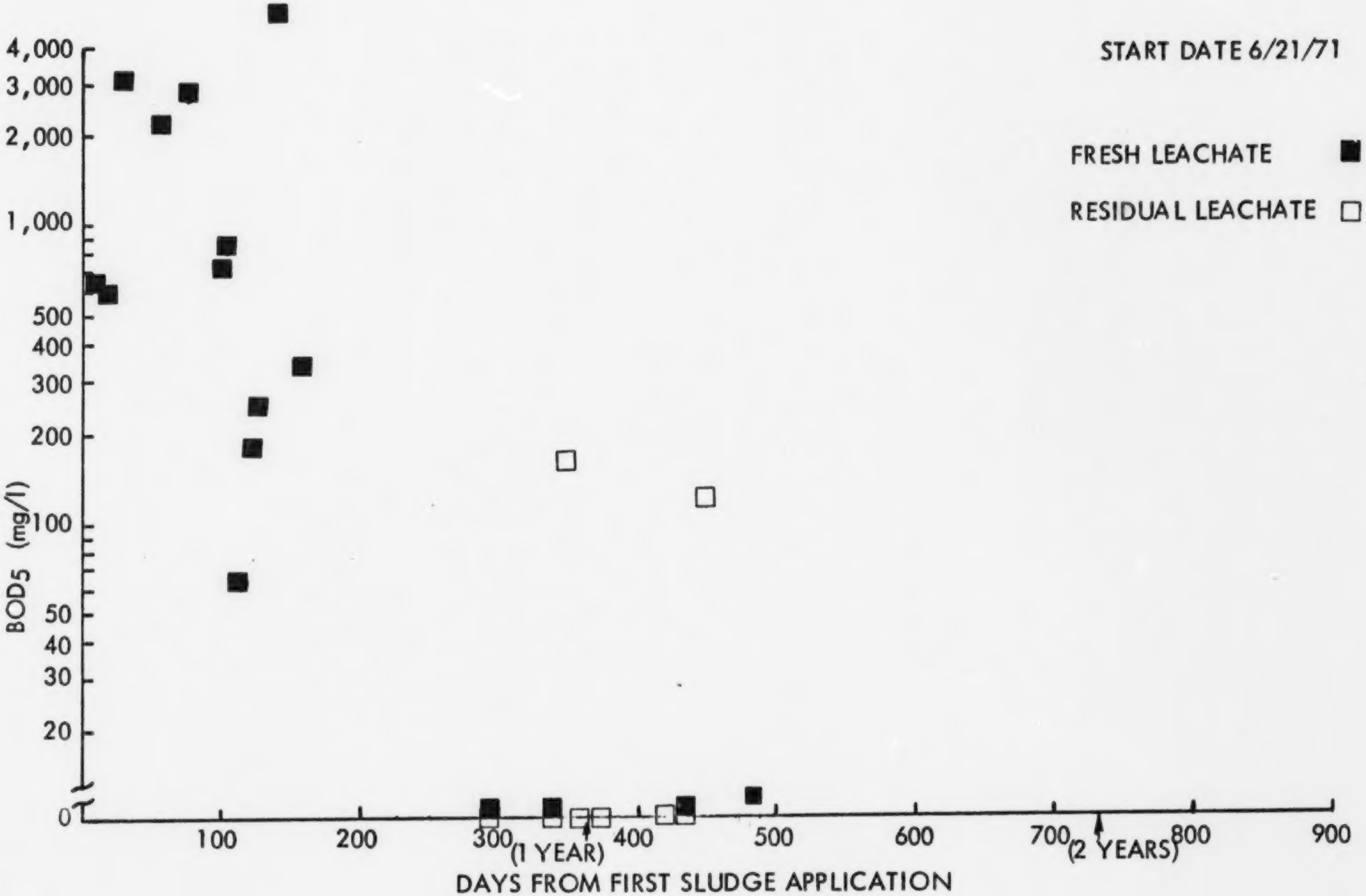
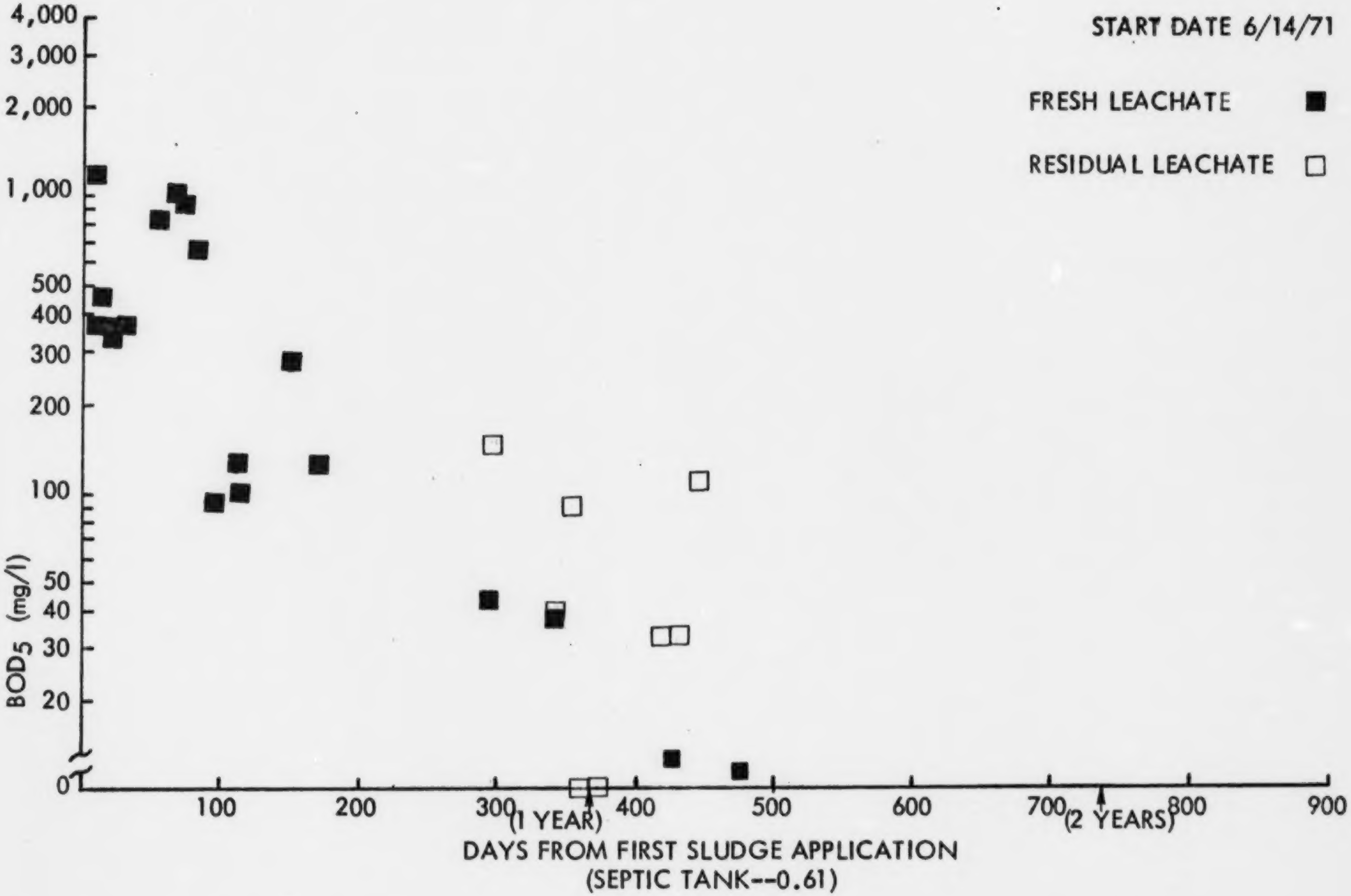


FIGURE D14
LEACHATE BOD_5 VS. TIME
DRUM NO. 15

CITY OF OCEANSIDE/E.P.A.



CITY OF OCEANSIDE/E.P.A.

FIGURE D15
LEACHATE BOD_5 VS. TIME
DRUM NO. 16

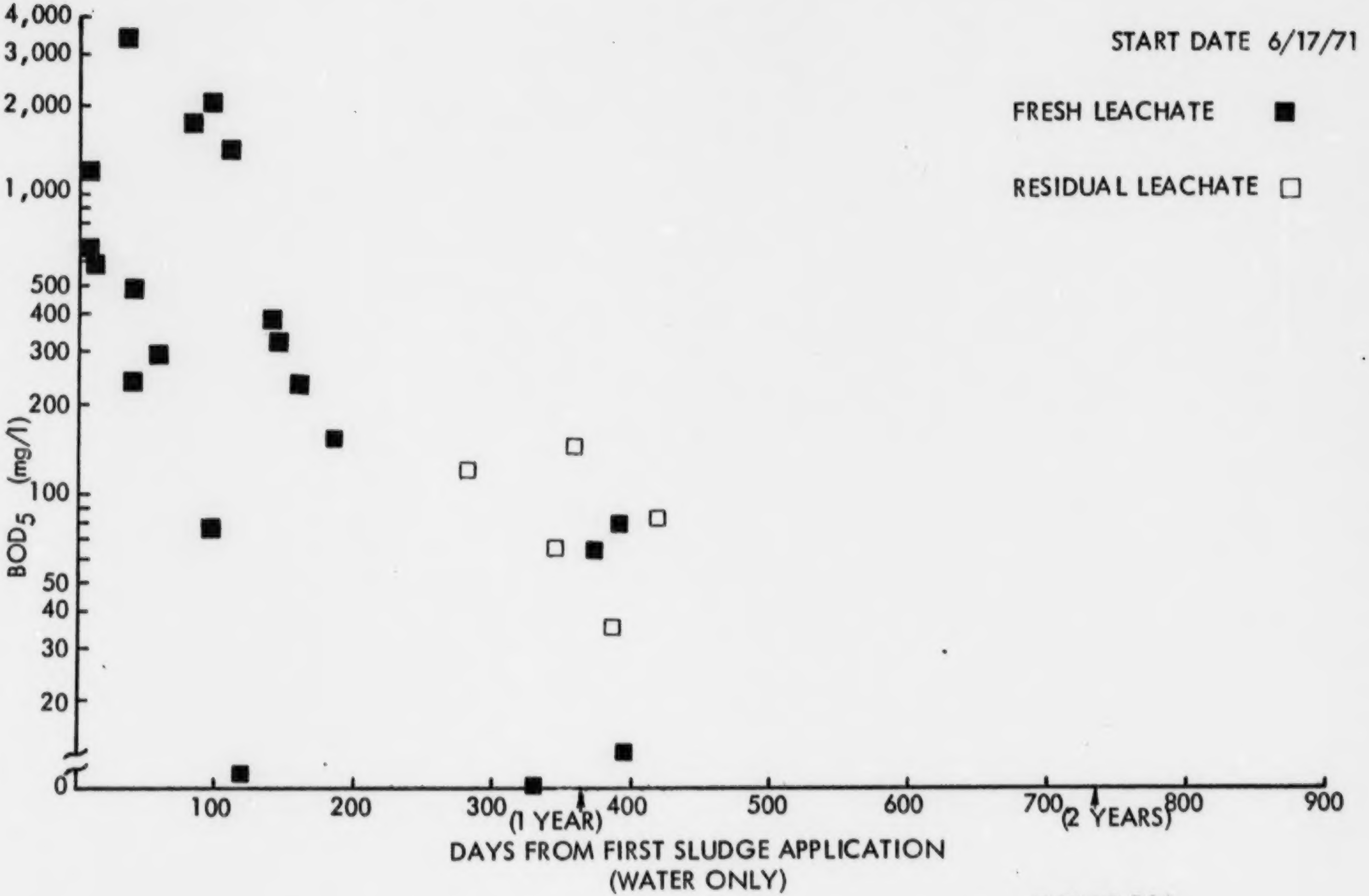


FIGURE D16
LEACHATE BOD_5 VS. TIME
DRUM NO. 17

CITY OF OCEANSIDE/E.P.A.

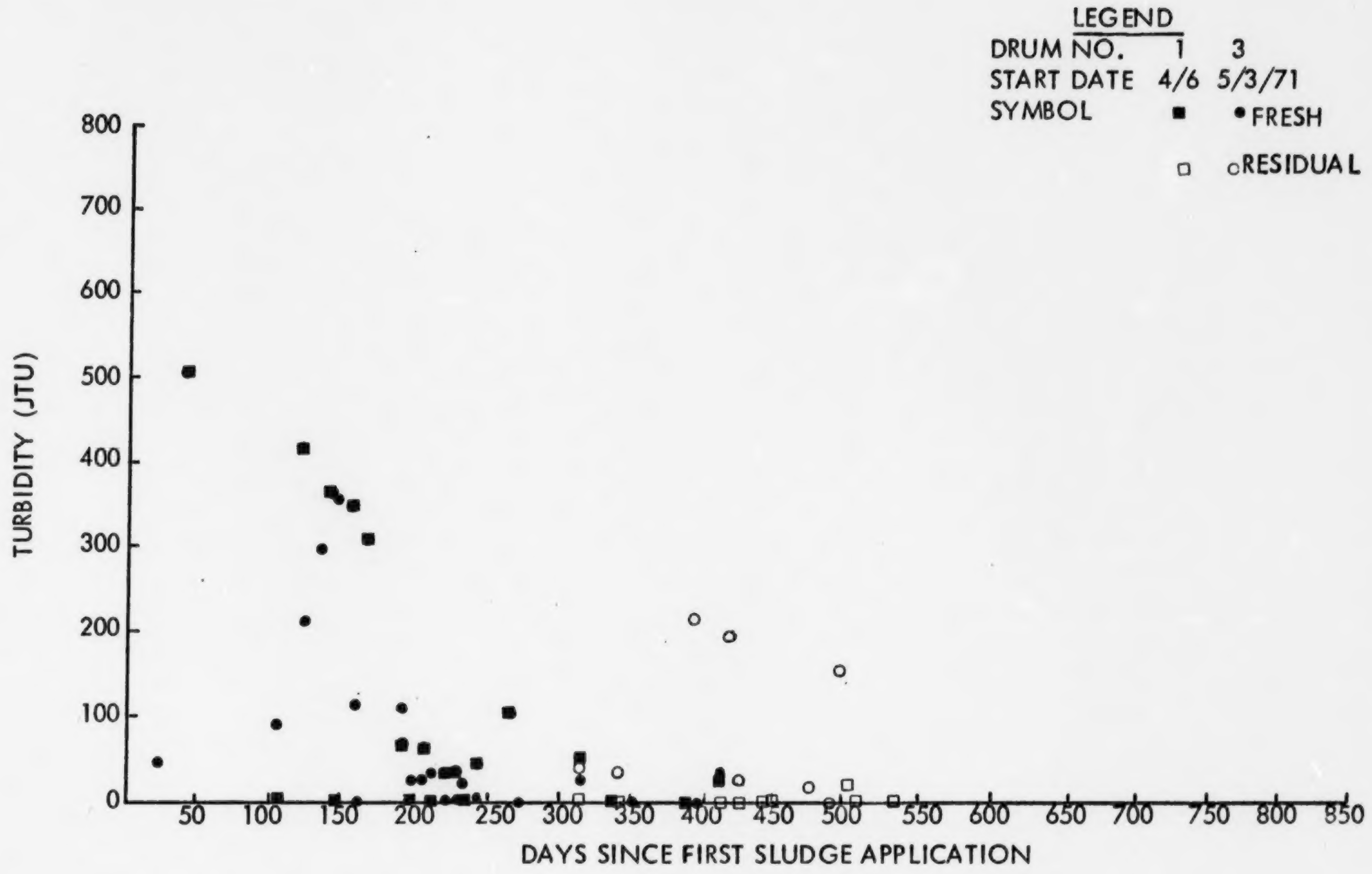
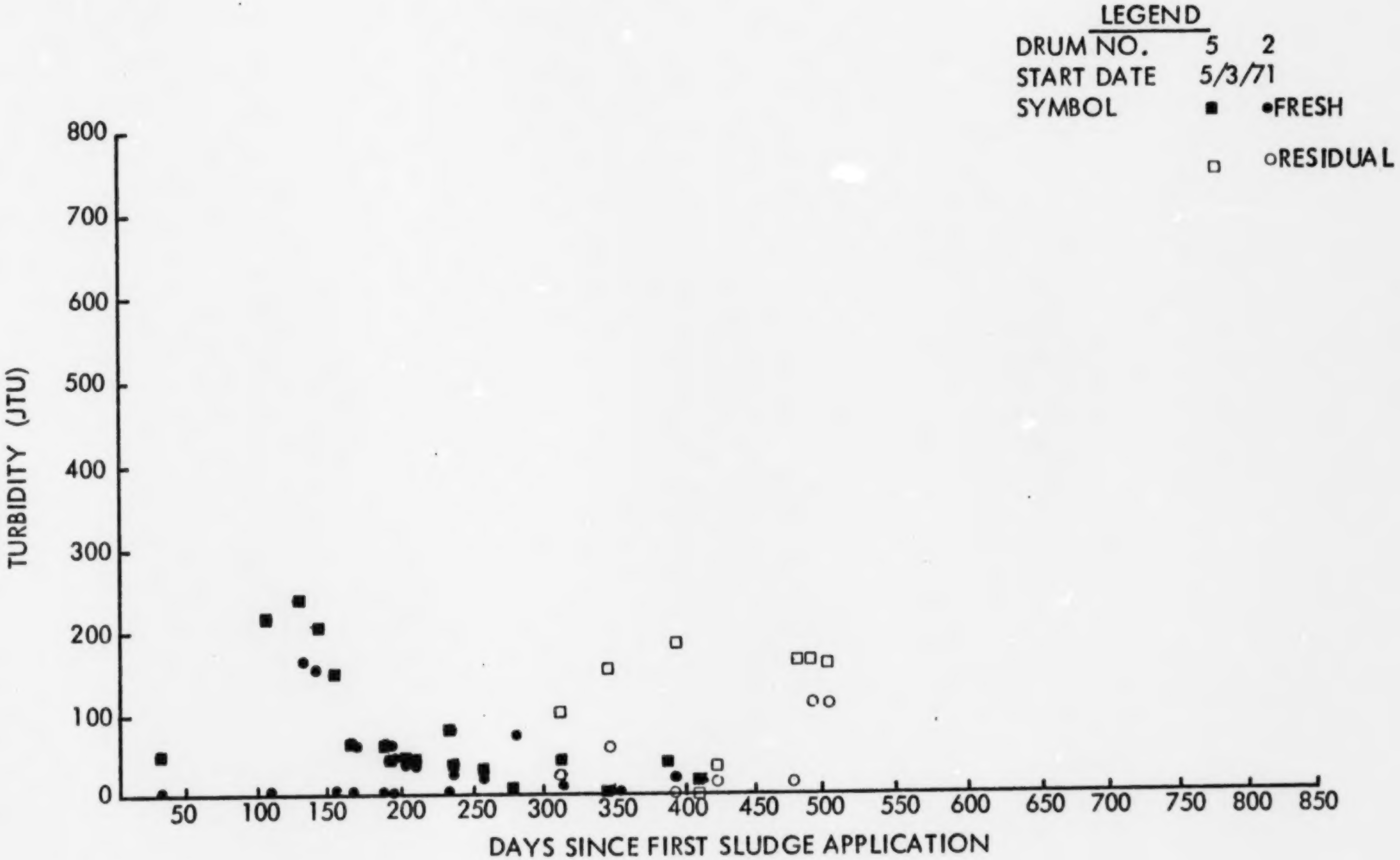
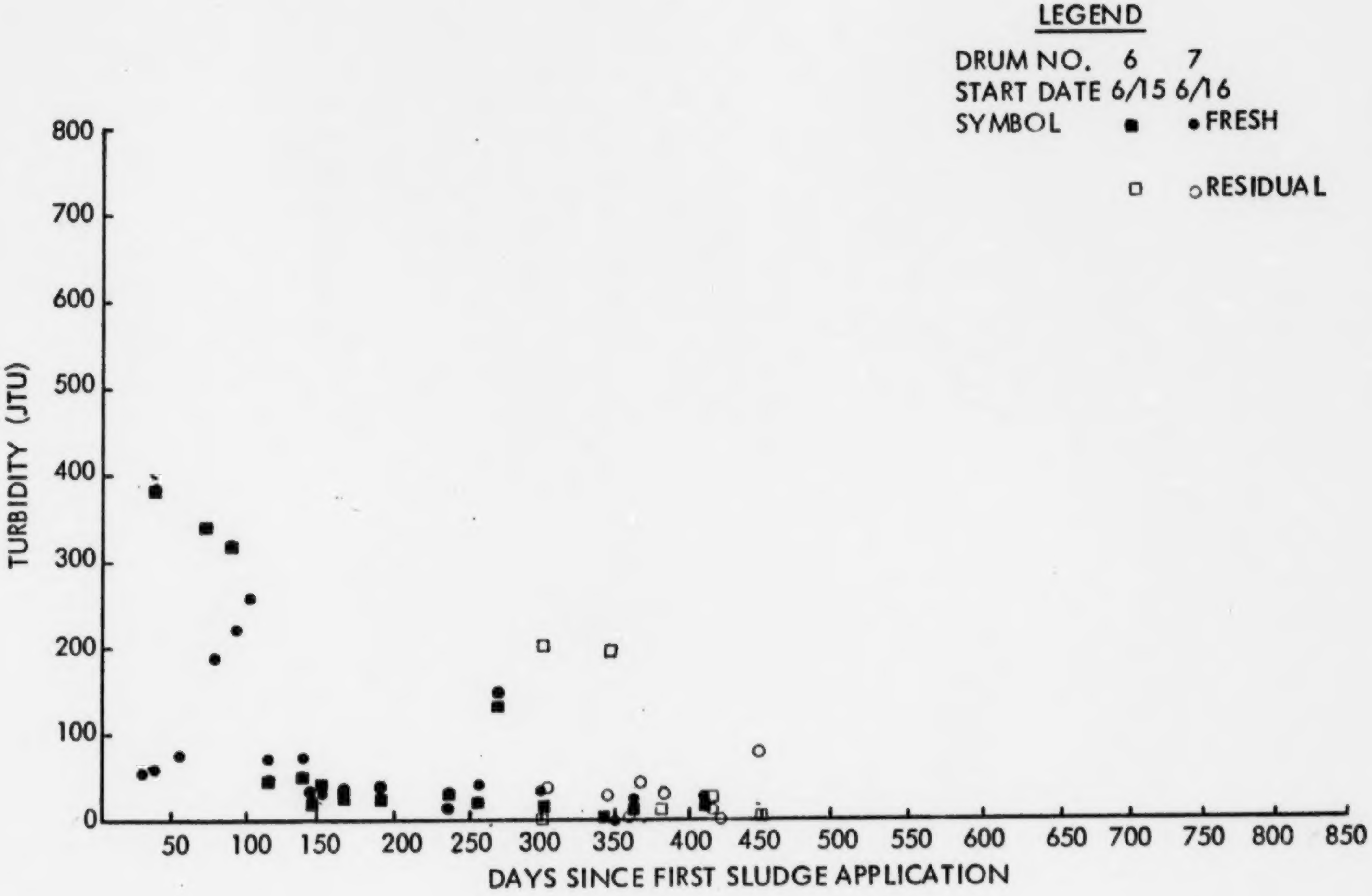


FIGURE D17
TURBIDITY OF LEACHATES



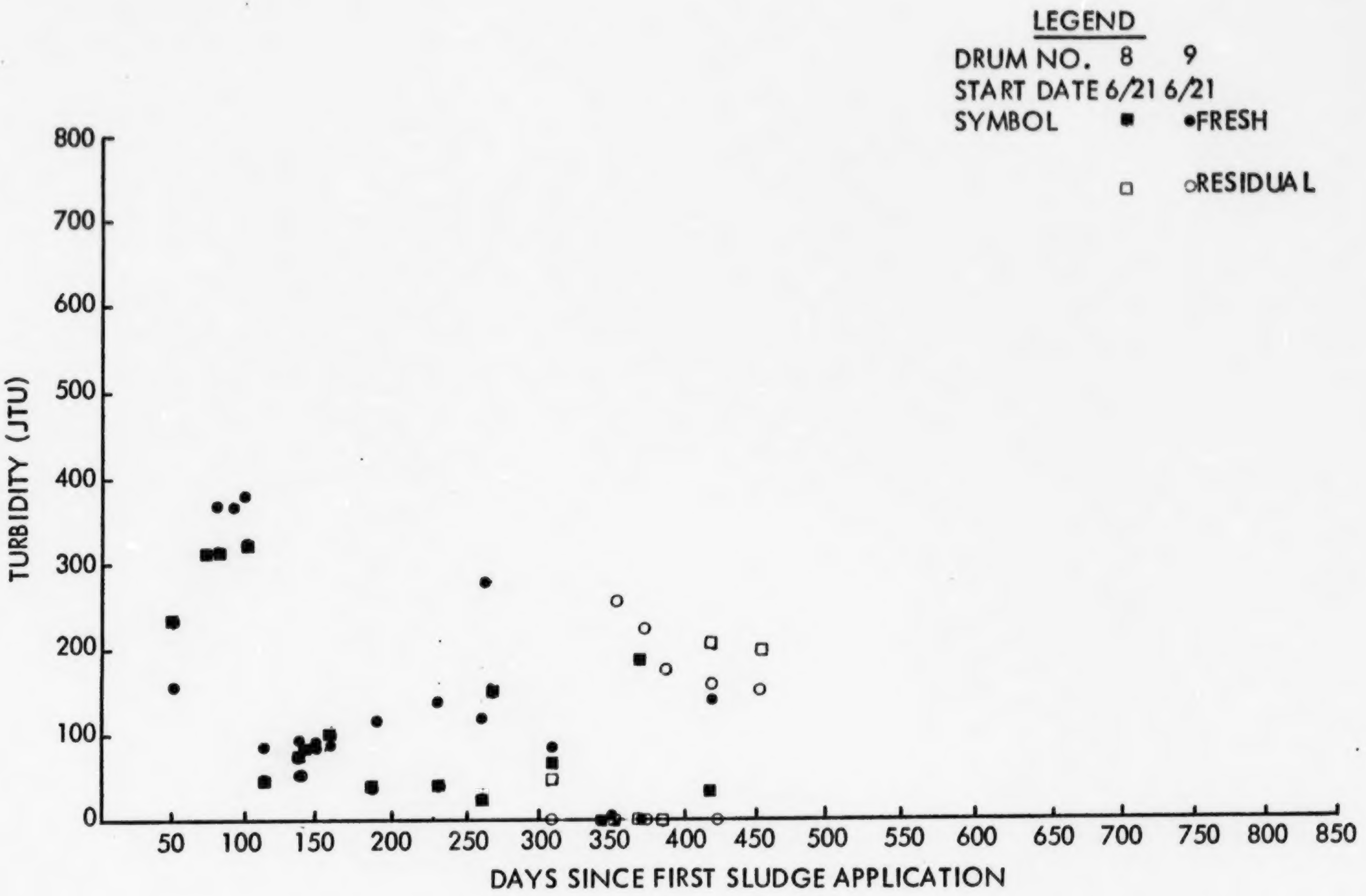
CITY OF OCEANSIDE/E.P.A.

FIGURE D18
TURBIDITY OF LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D19
TURBIDITY OF LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D20
TURBIDITY OF LEACHATES

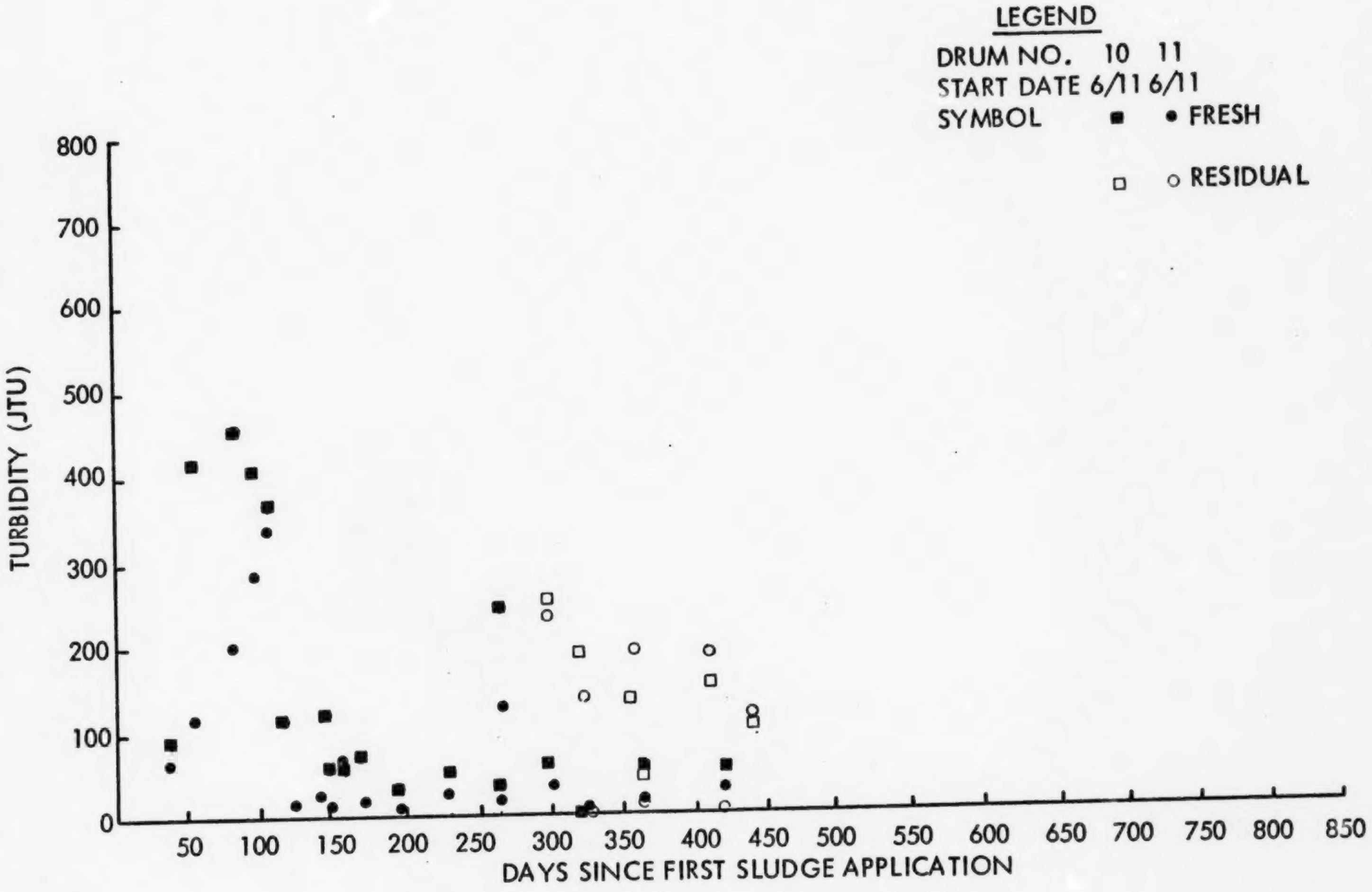
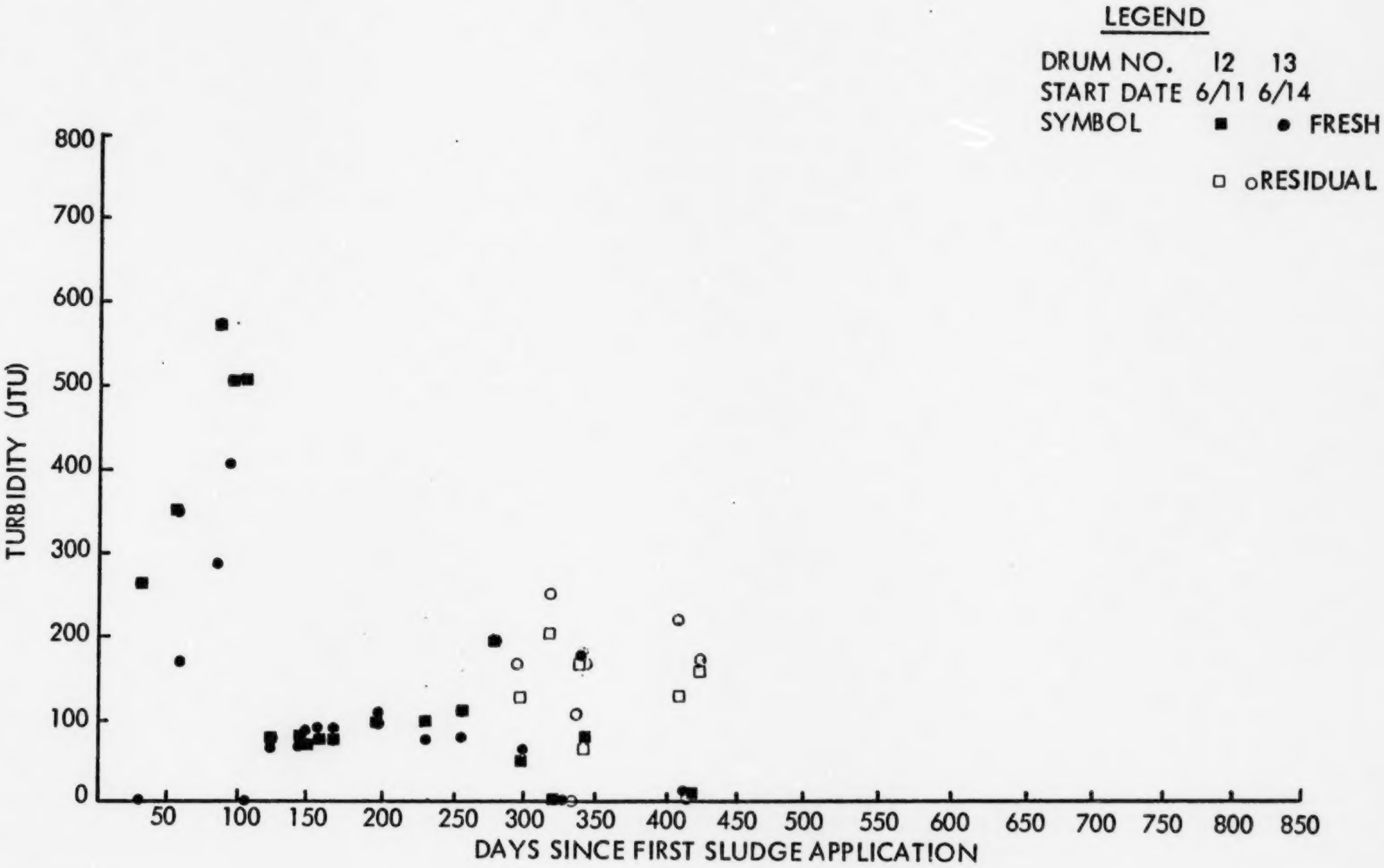
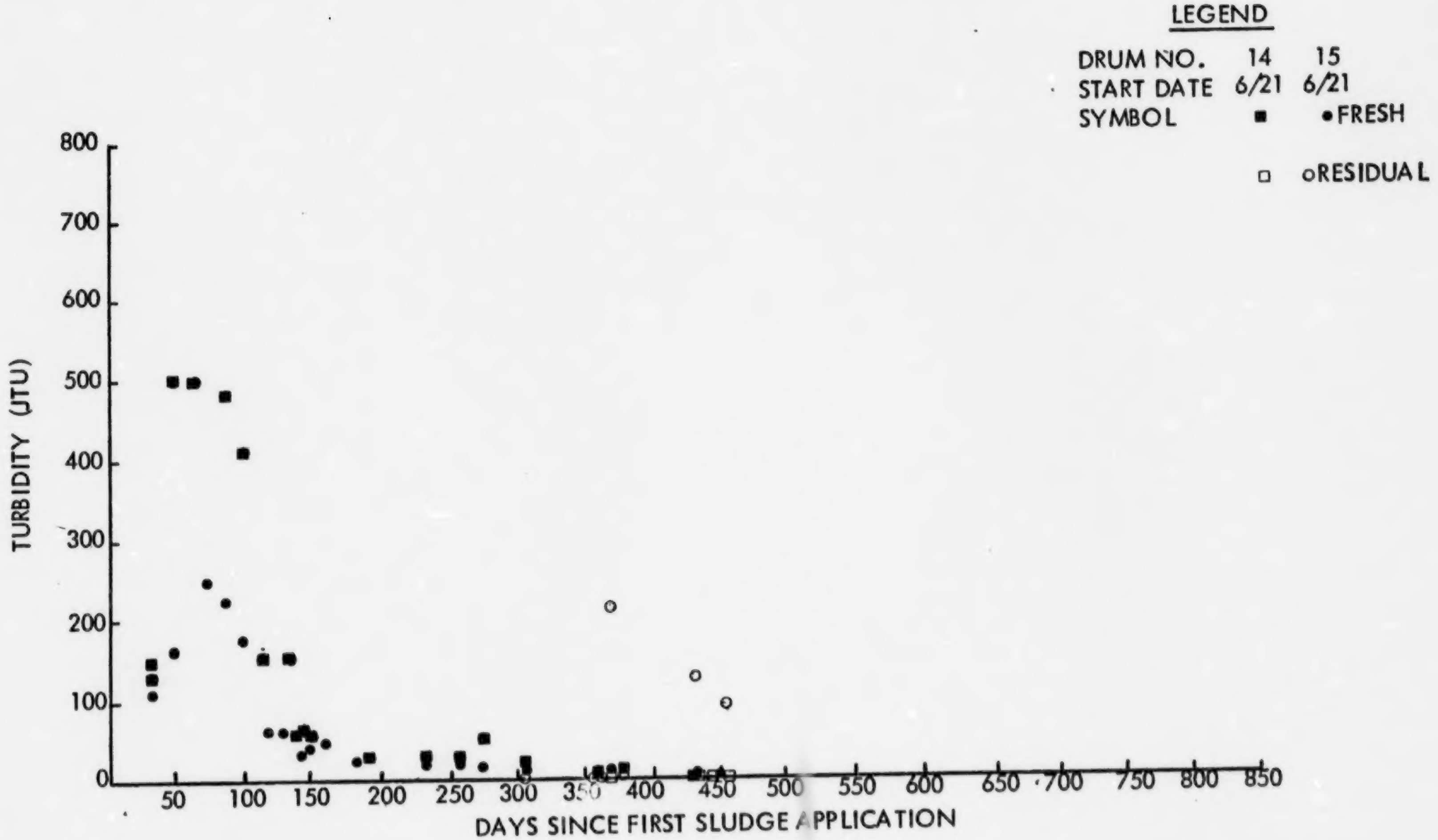


FIGURE D21
TURBIDITY OF LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D22
TURBIDITY OF LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D23
TURBIDITY OF LEACHATES

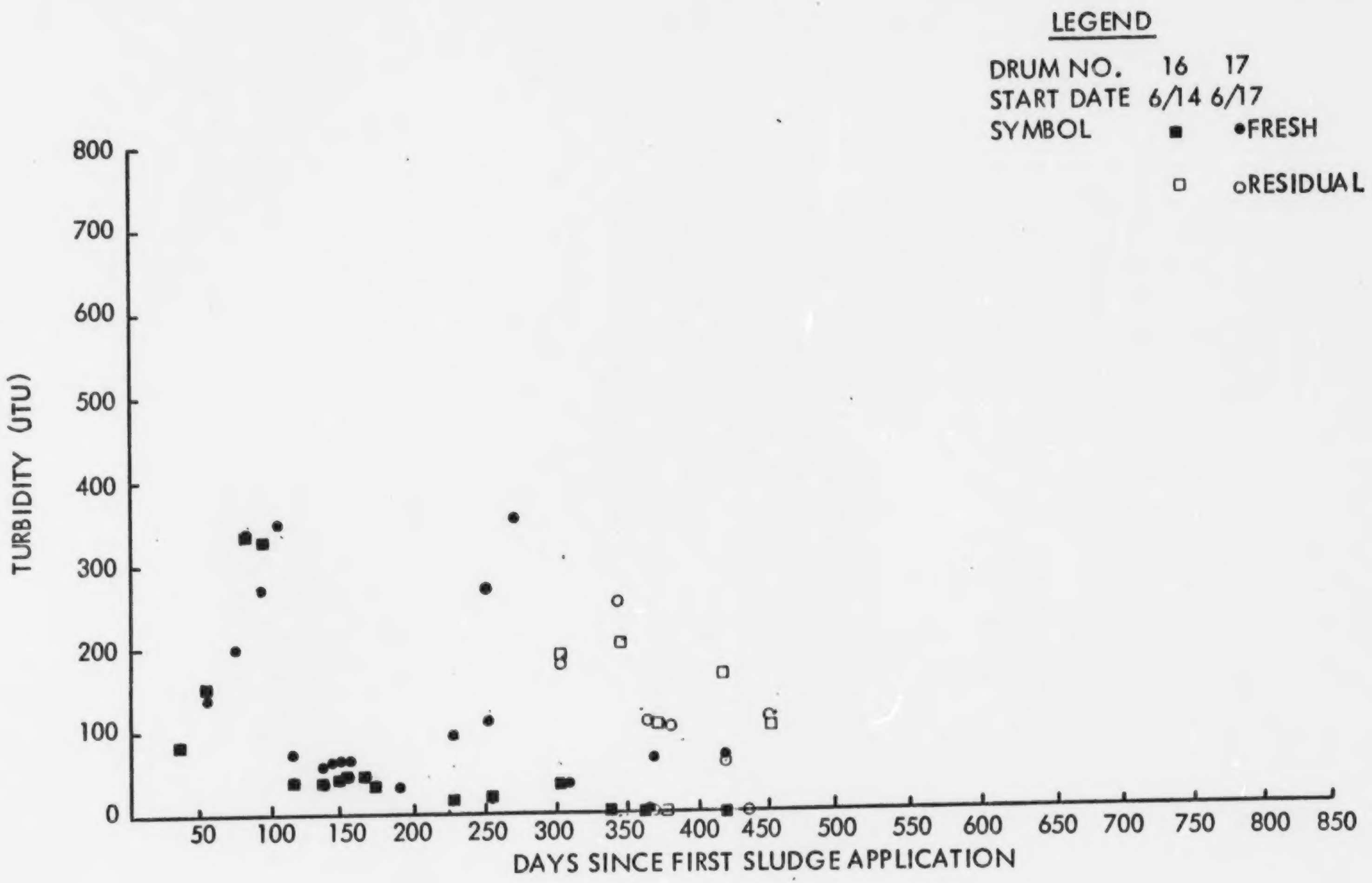
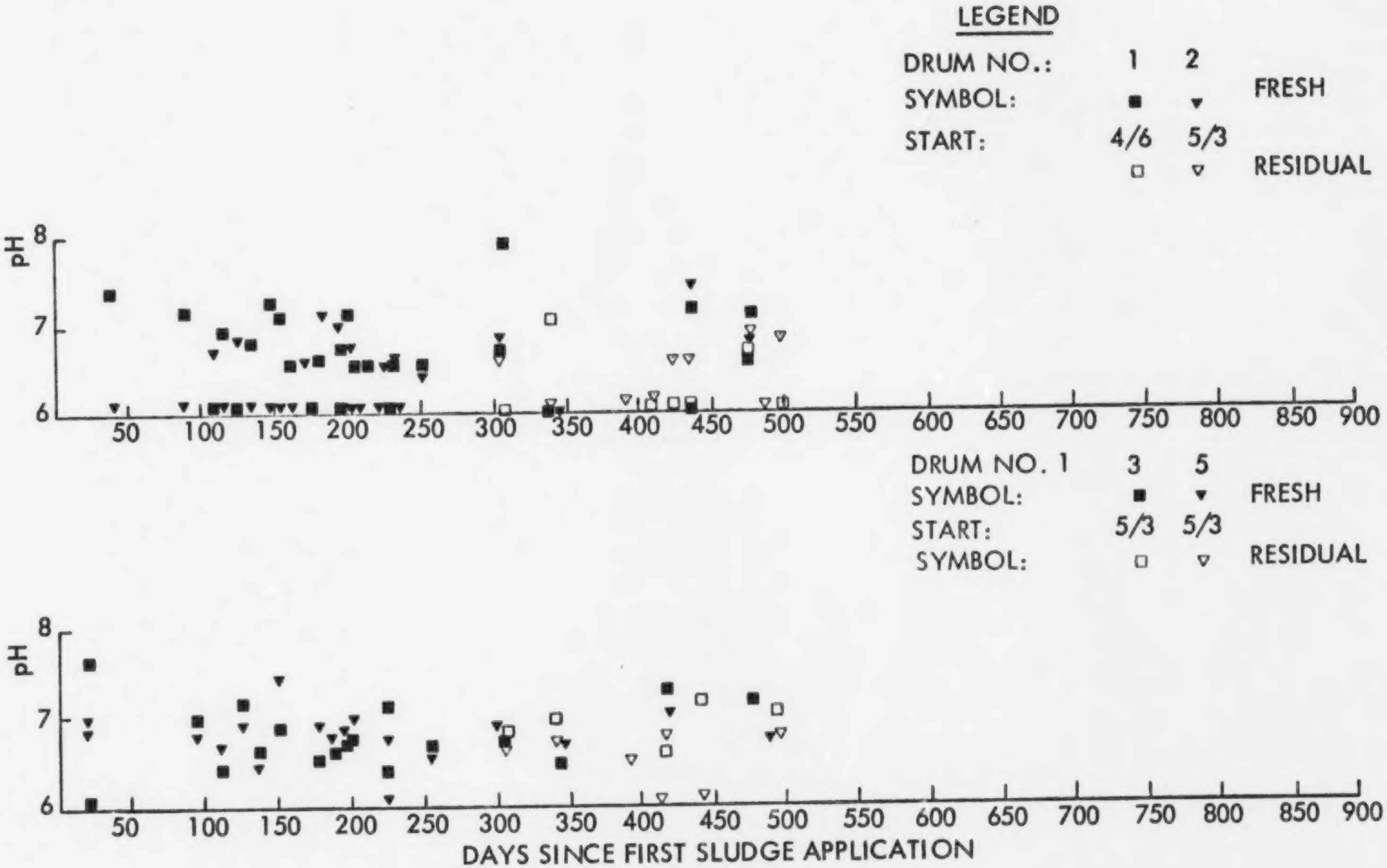


FIGURE D24
TURBIDITY OF LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D25
pH OF LEACHATES

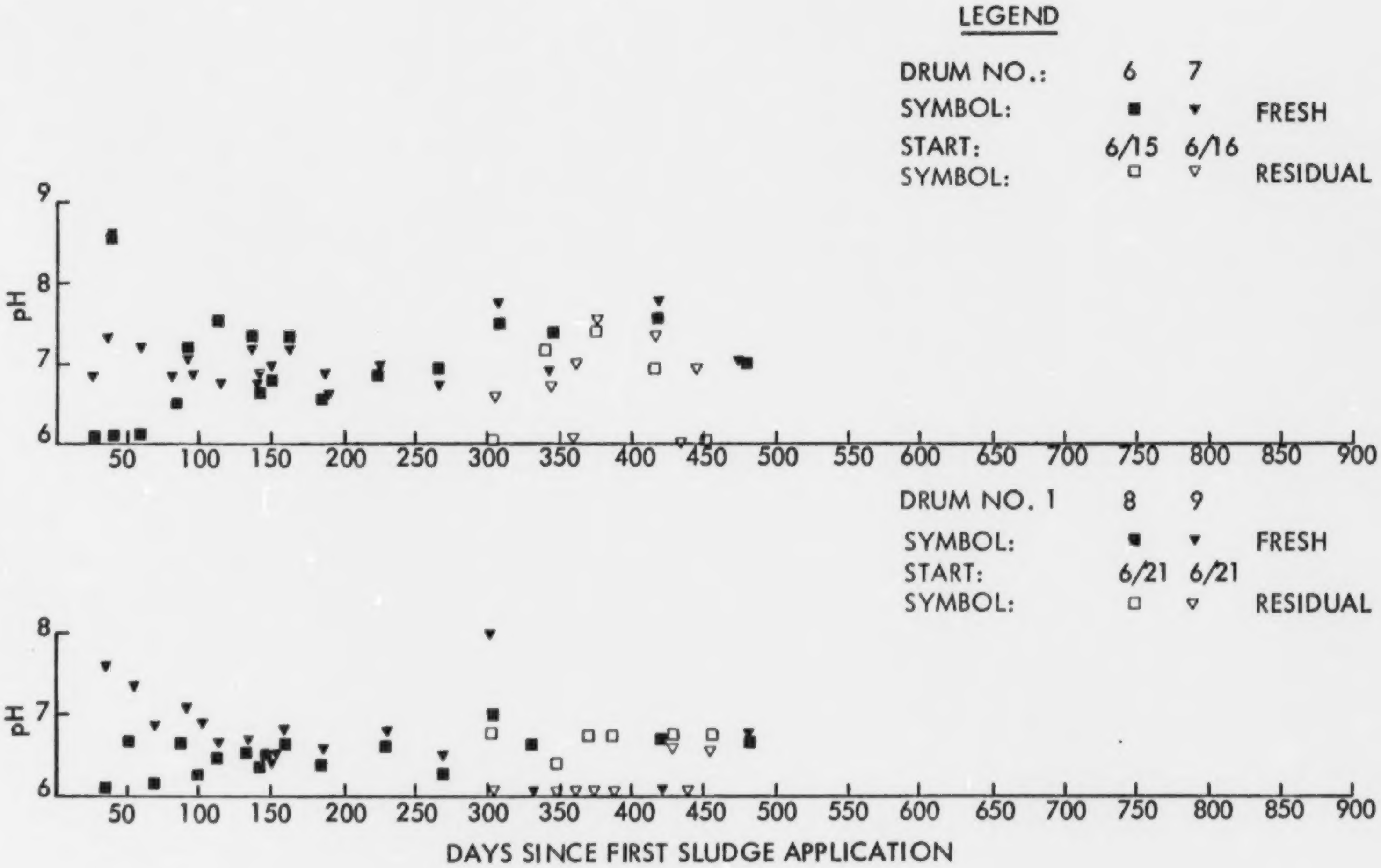


FIGURE D26
pH OF LEACHATES

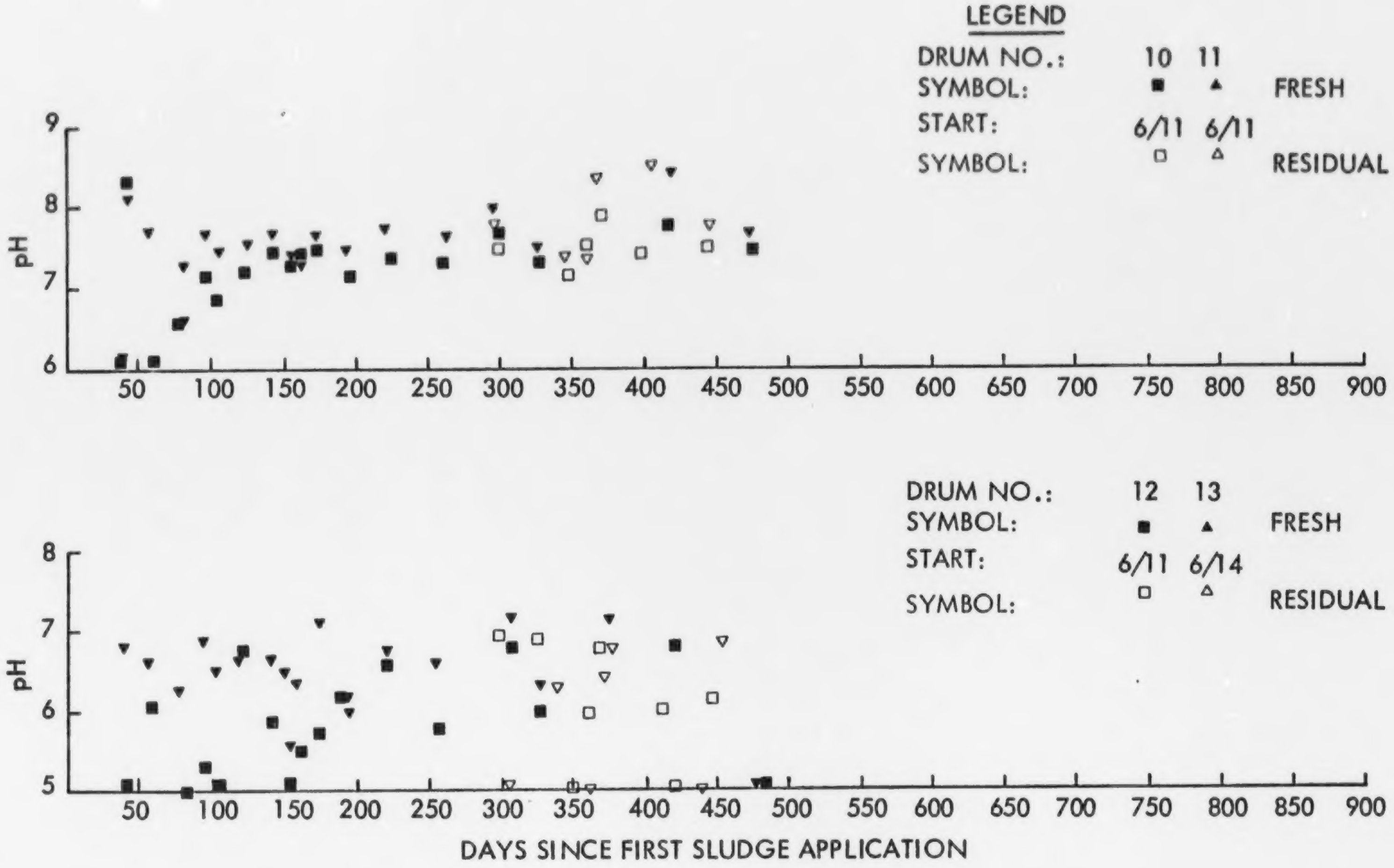
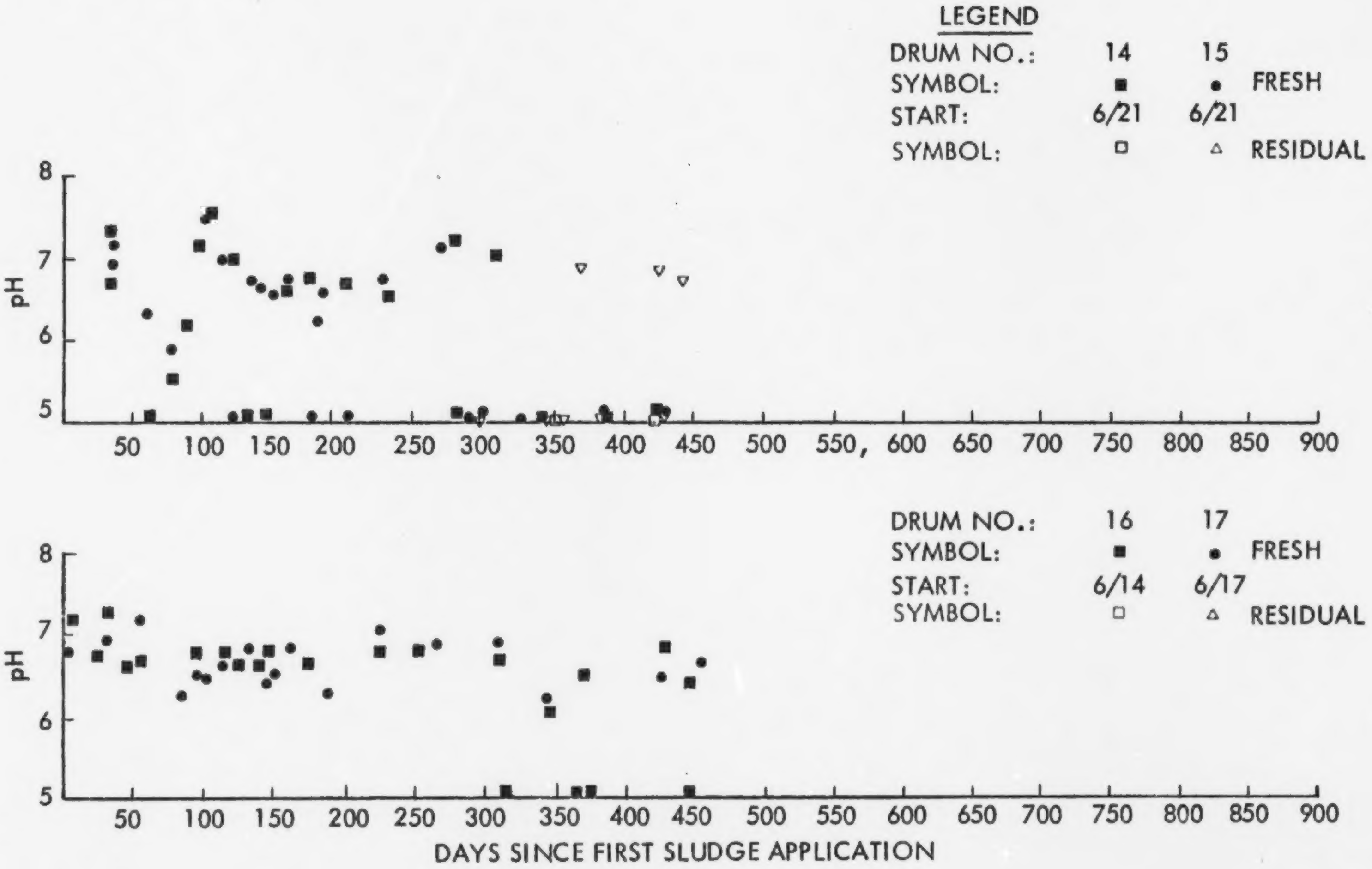


FIGURE D27
pH OF LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D28
pH OF LEACHATES

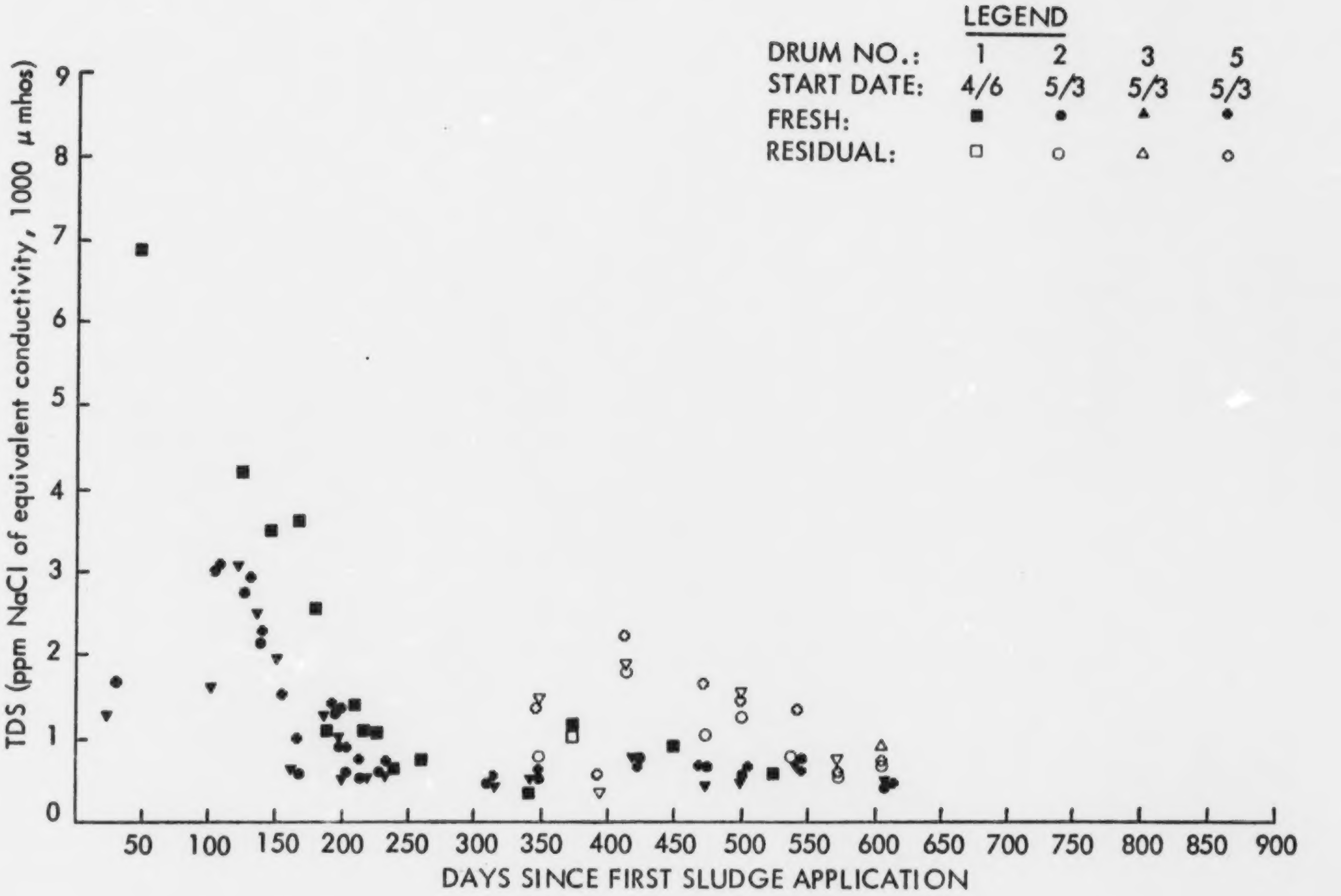


FIGURE D29
TOTAL DISSOLVED SALTS
IN LEACHATES

CITY OF OCEANSIDE/E.P.A

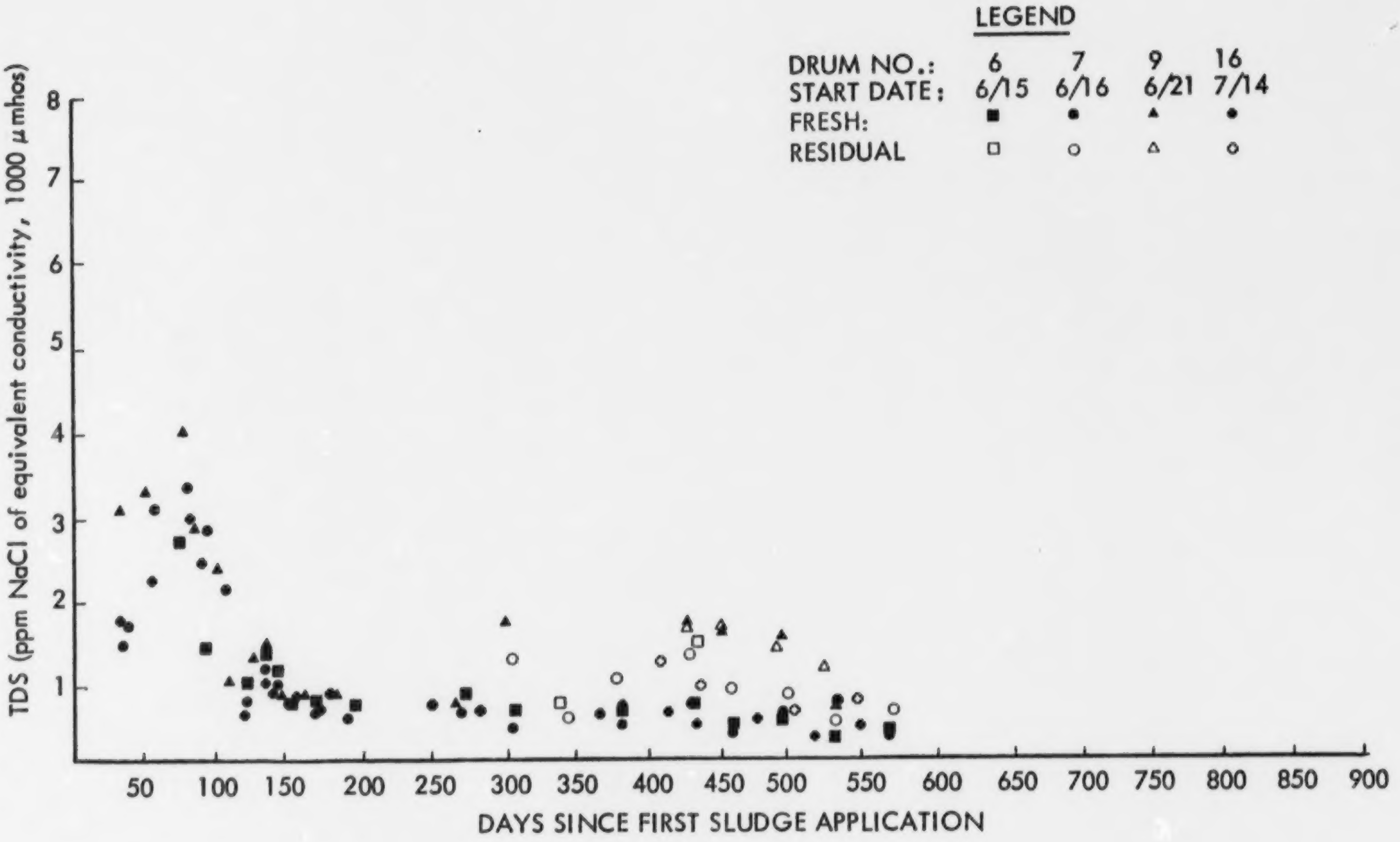


FIGURE D30
TOTAL DISSOLVED SALTS
IN LEACHATES

CITY OF OCEANSIDE/E.P.A.

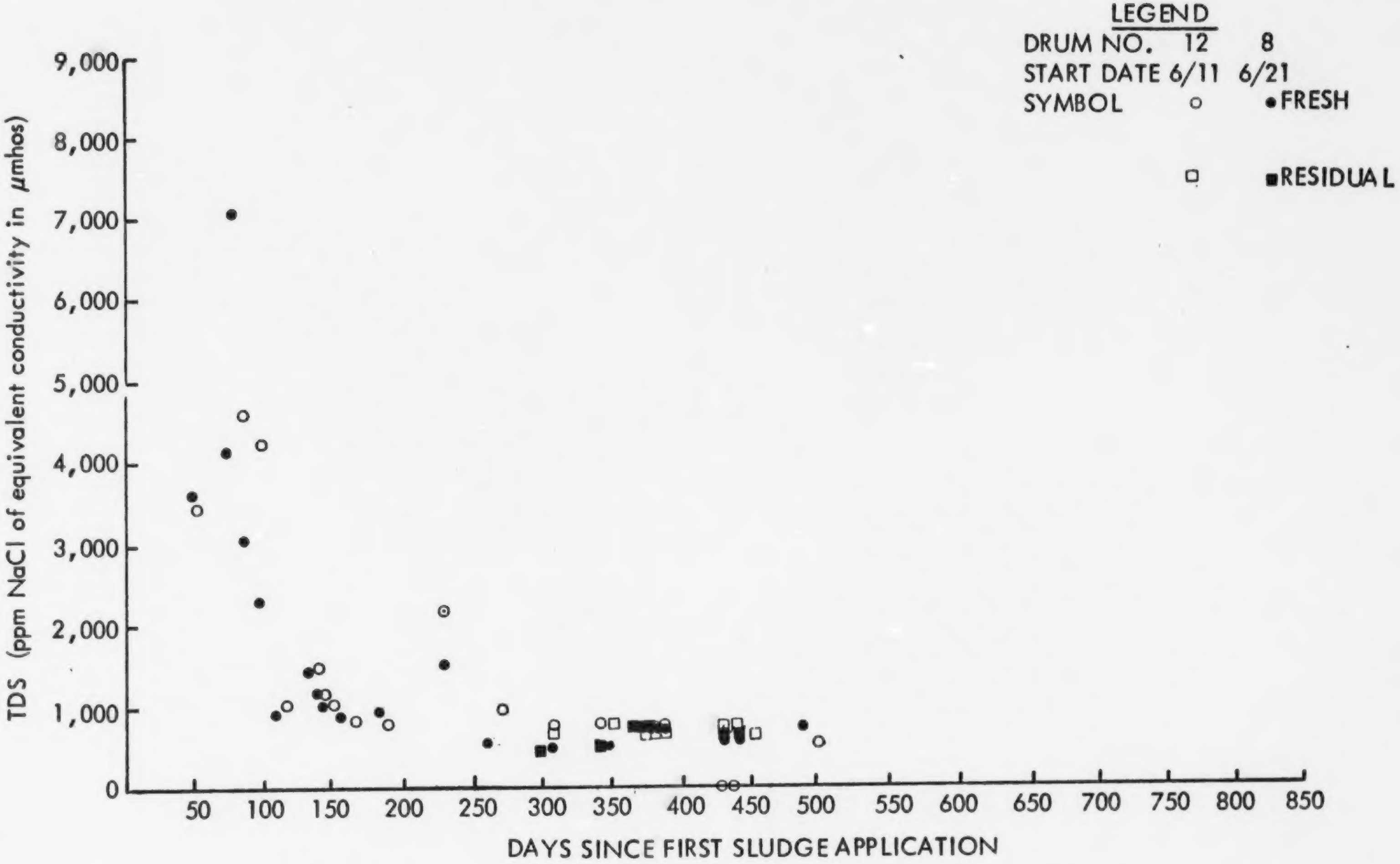


FIGURE D31
TOTAL DISSOLVED SALTS
IN LEACHATES

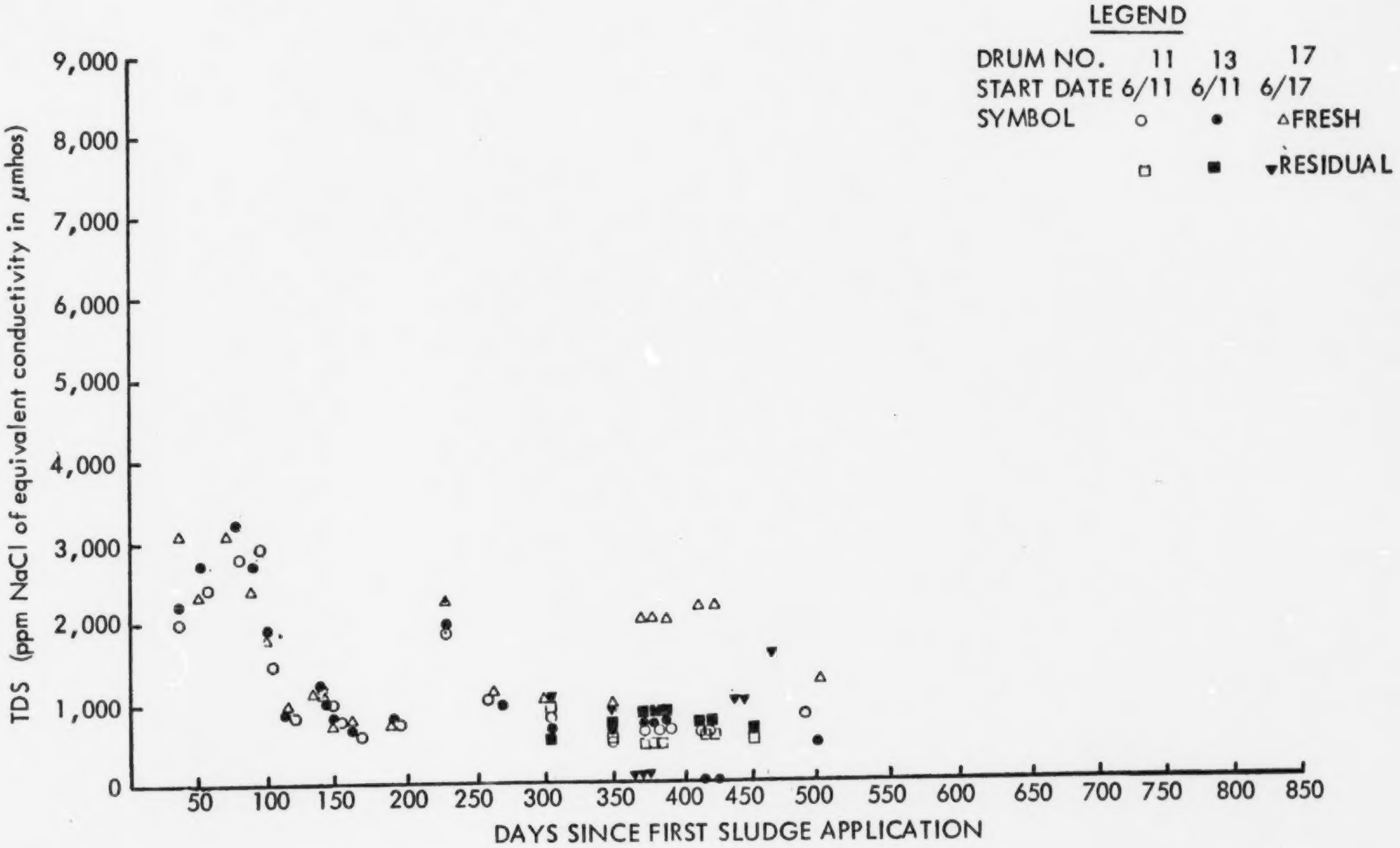
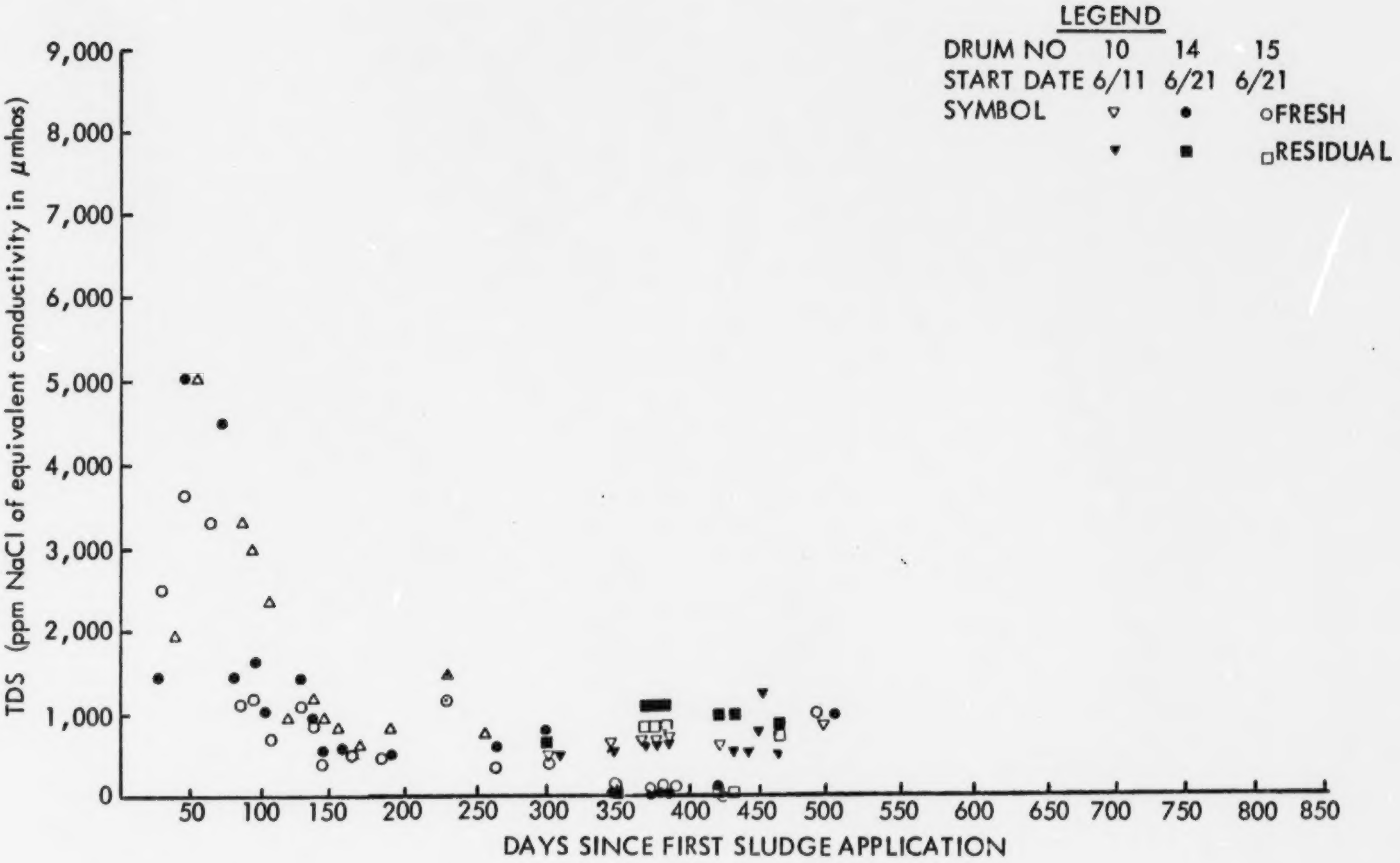


FIGURE D32
TOTAL DISSOLVED SALTS
IN LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D33
TOTAL DISSOLVED SALTS
IN LEACHATES

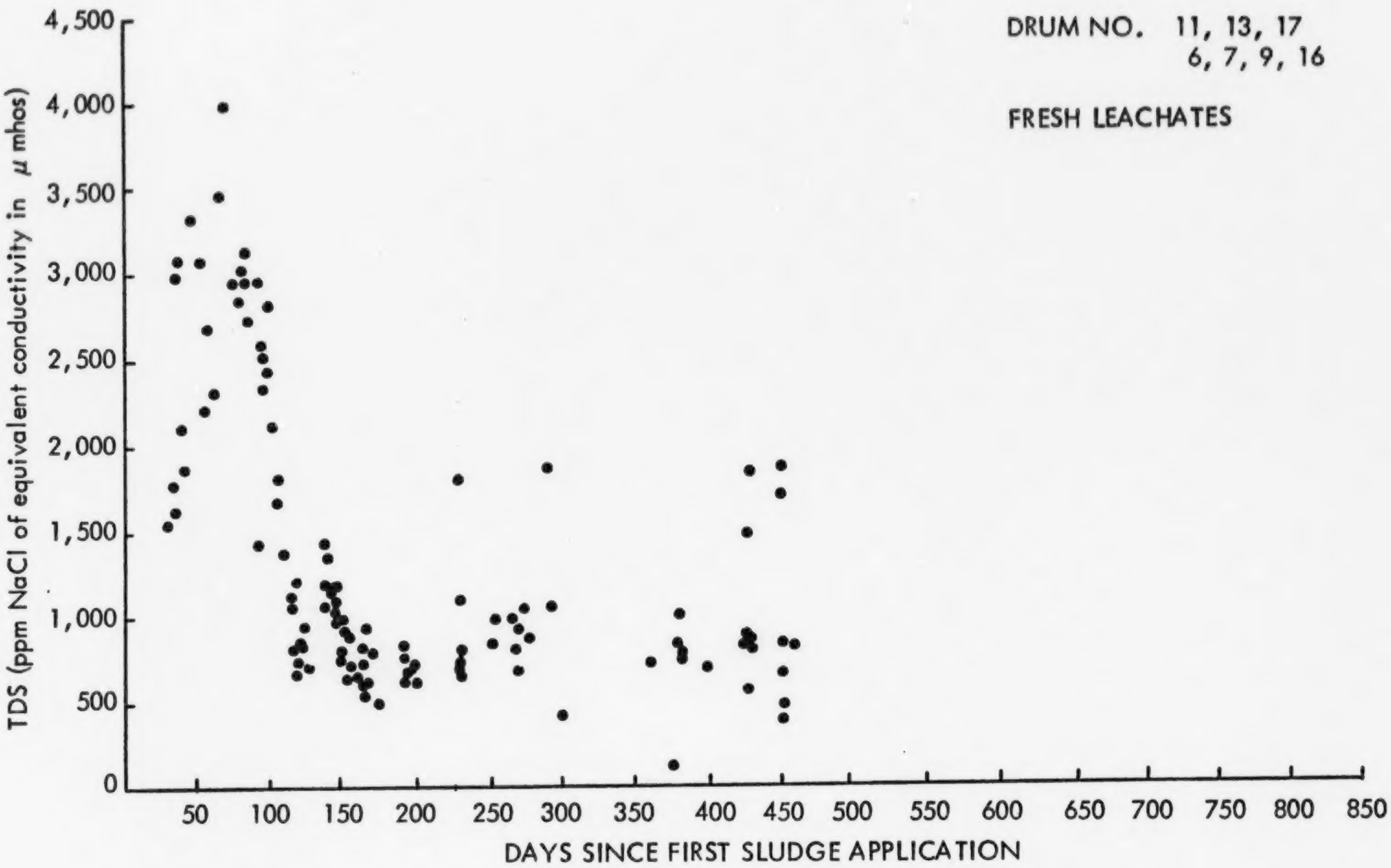
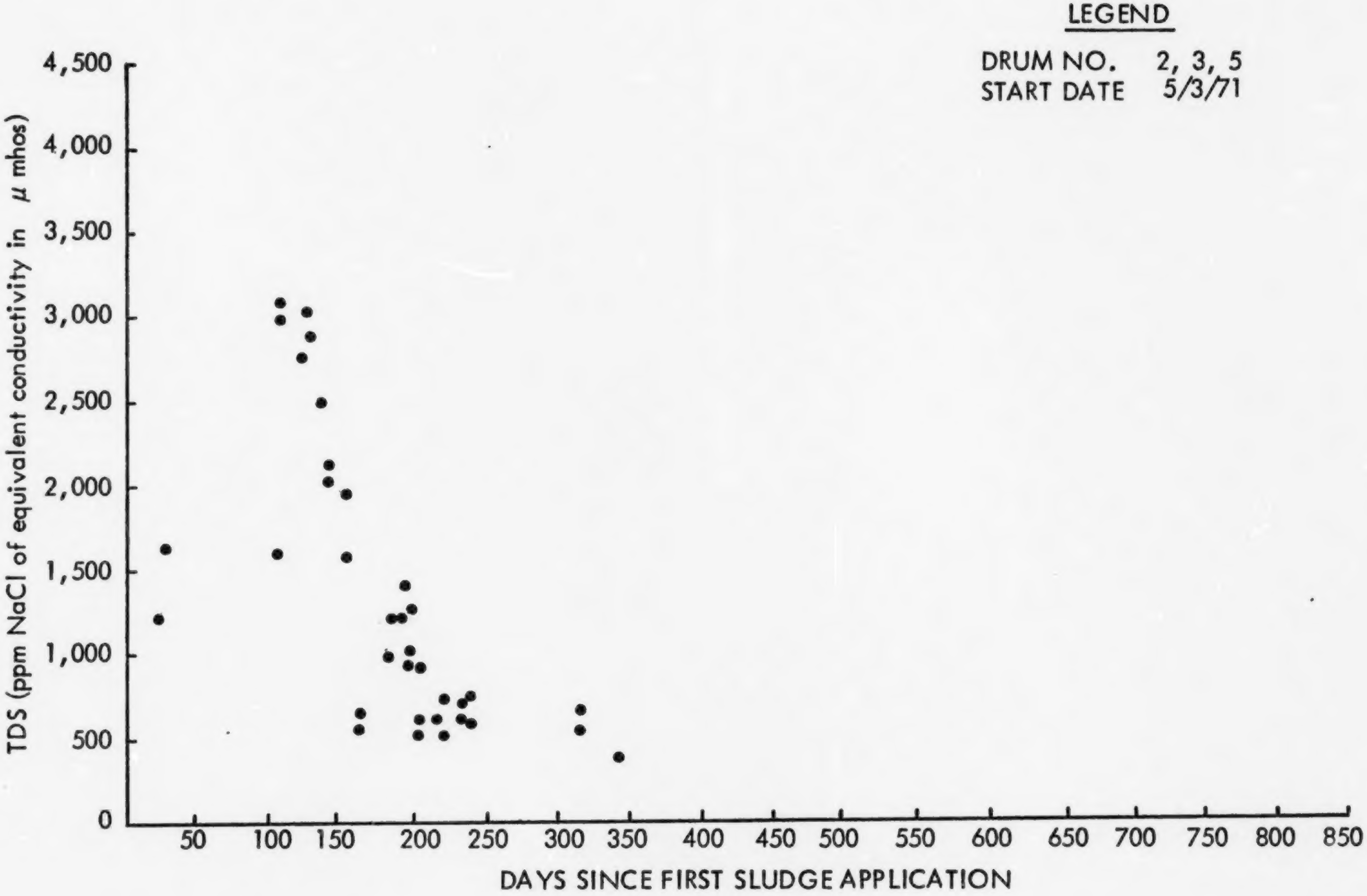


FIGURE D34
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D35
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES

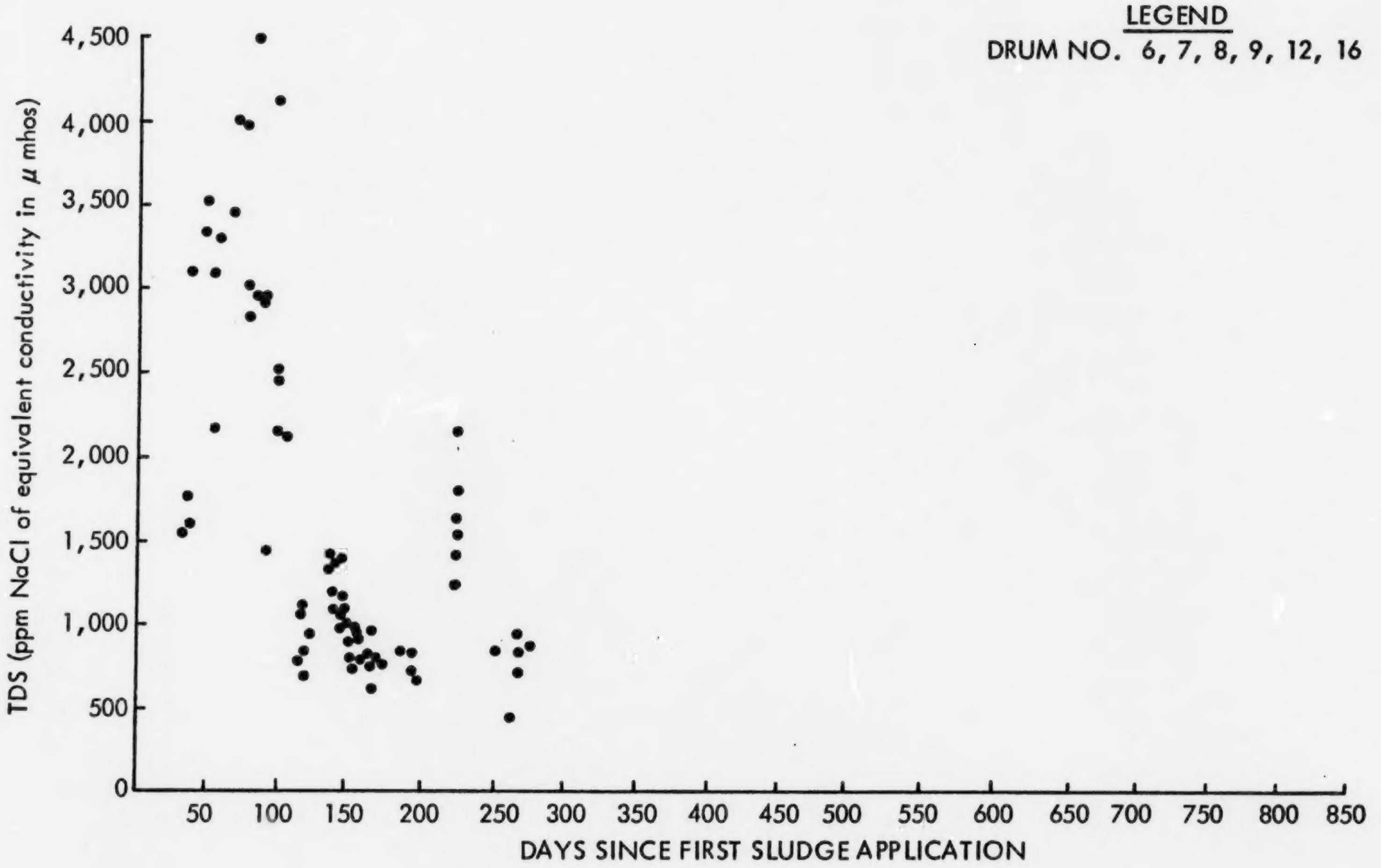
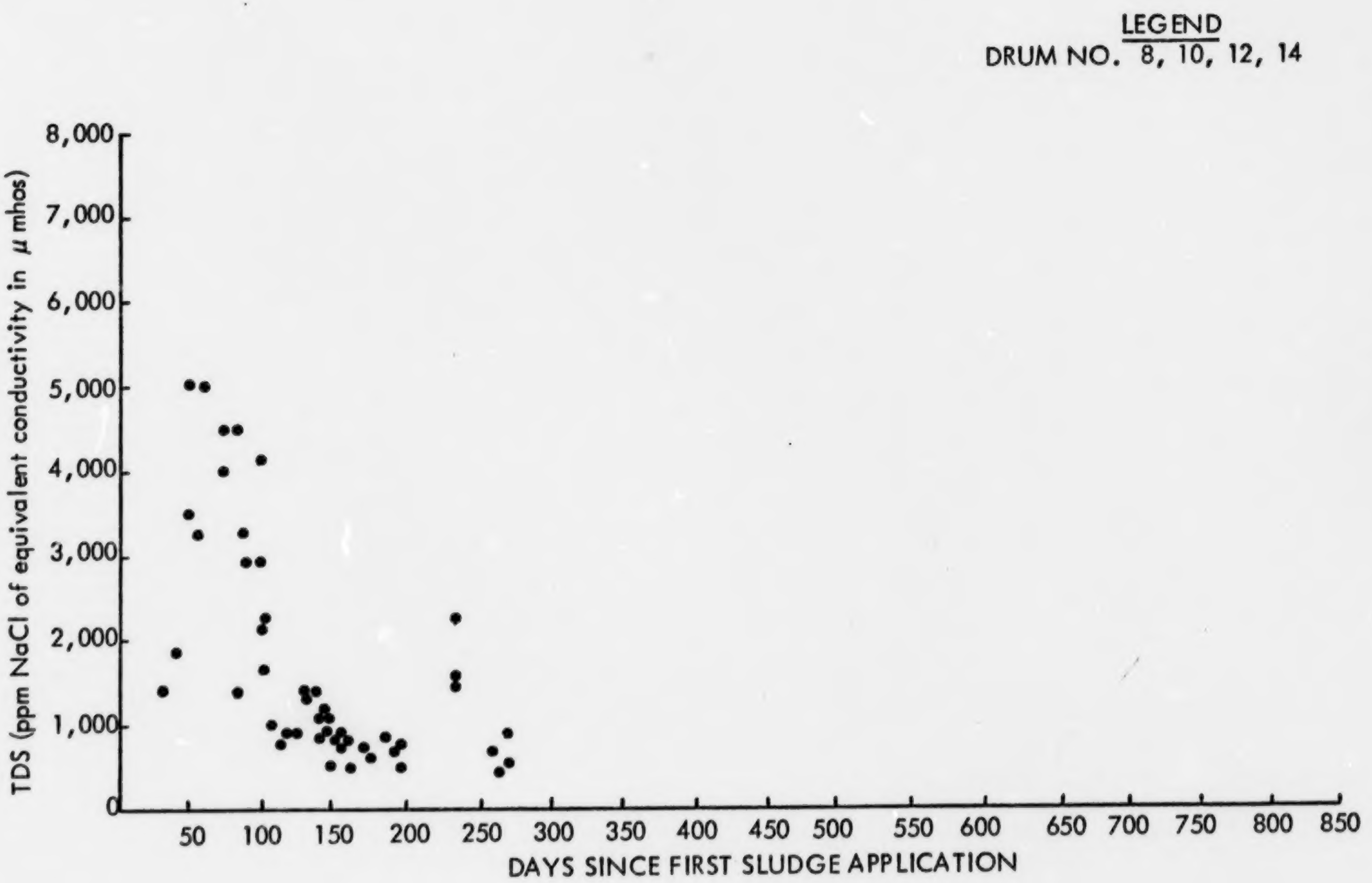
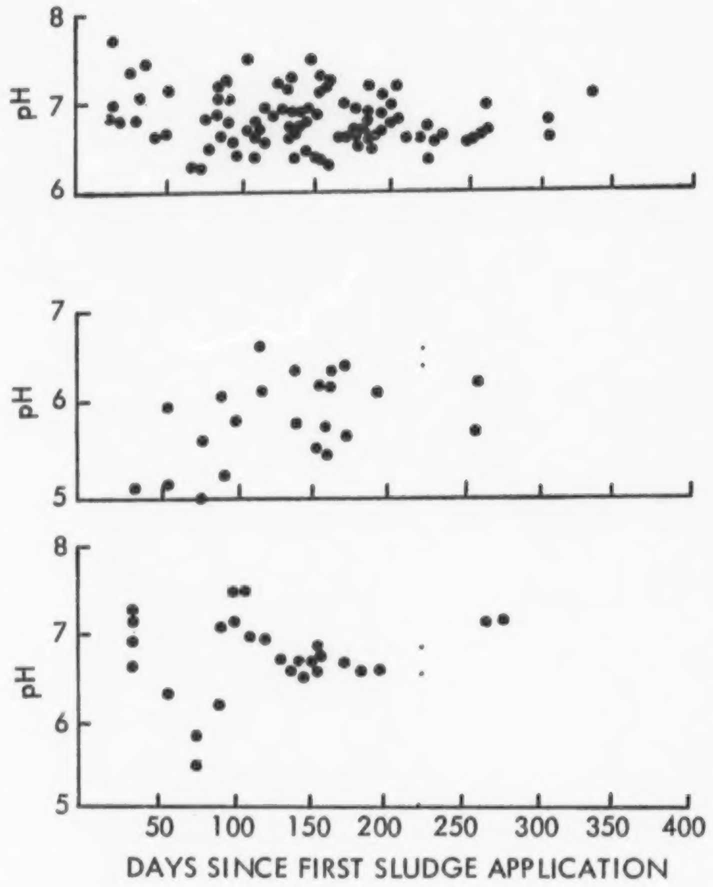


FIGURE D36
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES



CITY OF OCEANSIDE/E.P.A.

FIGURE D37
TOTAL DISSOLVED SALTS
(COMPOSITE) IN LEACHATES

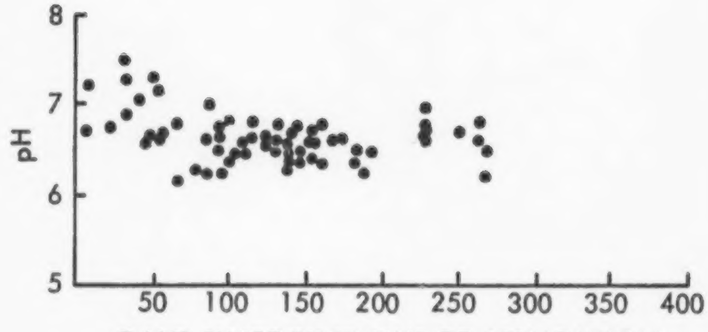


DRUM NO.: 1,2,3,5,6,
7,11,13

DRUM NO.: 10,12

DRUM NO.: 14,15

FIGURE D38
pH OF LEACHATES--COMPOSITES



DRUM NO.: 8,9,11,16,17

CITY OF OCEANSIDE/E.P.A.

FIGURE D39
pH OF LEACHATES--COMPOSITES

TABLE D1

TOTAL METALS IN TEST DRUM LEACHATES COMPOSITE SAMPLES DURING 1972

Drum	Days since filling *	Quantity, lbs metals per lb dry wt solid waste (plus sludge solids where applicable) Mg x 10^{-5}	Zn x 10^{-7}	Fe x 10^{-6}
1	267-450	1.44	9.60	2.58
2	241-424	0.15	2.25	7.20
3	241-424	0.96	4.00	3.44
5	241-424	1.36	12.80	3.44
6	198-381	2.14	4.80	2.80
7	196-379	1.09	3.20	2.75
8	192-375	0.99	4.80	3.12
9	192-375	2.24	7.20	4.72
10	192-375	0.61	3.20	2.80
11	192-375	2.40	4.00	13.00
12	201-384	1.92	2.73	3.22
13	201-384	1.09	4.80	3.12
14	200-383	1.35	27.50	3.22
15	192-373	1.65	4.50	3.22
16	177-360	1.60	24.70	6.95
17	196-379	1.99	9.00	3.66

* The amount of equivalent annual rainfall on all the drums during this time period was 11.9 inches.

Water only - this is representative of ordinary landfills.

APPENDIX E

FIELD TEST OF SLUDGE DISPOSAL

FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
6/25	CONSULTANT 96 cu yd	1,750	70±	Low	Overcast	Septic, sulfide	At regular landfill	None	birds	Sludge ran into fill OK
7/13	3 loads	5,250	83	Calm	Sunny	No	None	small birds	small birds	After 1½ days uncovered test area begins to give odors. Can't identify other than decaying garbage
7/20	3 loads	1,750	80	Calm	Overcast	Yes, garbage	None	6 seagulls	None	Sludge is not being spread evenly over trash.
7/20 #	CONSULTANT 96 cu yd	1,750	70	Easterly breeze	Cool	Slight	None or very little	flies walking on refuse and sludge		Counted at least 50 flies. Sludge ran down incline in rivulets and settled in pools at base. #Sludge & solid waste already placed
7/27	3 loads	1,750	84	Calm	Sunny	No	None	None	None	Sludge spread better this time. No run off.

*Enter - Calm, Low, Moderate, or High

+Enter - Sunny, Cloudy, Overcast, Showers, or Rain

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
7/27	CONSULTANT 96 cu yd	1,750	70	Moderate	Overcast	Downwind Sulfide, septic	No	None	50 birds	Ran sludge out in 3 locations from 2 pipes at rear of tank. Some pooled in refuse, most percolated in very fast. Cat operator says bottom layer holds better; top layer runs off faster; lower platform holds sludge best. Also thinks less pressure in 2 openings than before with 1 opening in tank.
8/3	3 loads	1,750	88	Calm	Sunny	Slight sewage odor	None	None	seagulls small birds	Test area does not seem to attract anything but flies
8/10	3 loads	1,750	86	Calm	Sunny	Negligible	None	None	None	
8/10	CONSULTANT		88	Moderate	Sunny	No	No	6 seagulls	6 seagulls	Slight leachate
8/17	3 loads	1,750	73	Moderate	Overcast	negligible	Some plastic bags	None	birds	Out of room at Brooks St. landfill. Dumped

*Enter - Calm, Low, Moderate, or High

+Enter - Sunny, Cloudy, Overcast, Showers, or Rain

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
										these loads at new landfill off Mission Drive
8/23	CONSULTANT 96 cu yd	1,750	80	Westerly Low	Sunny	Digested sludge	None	flies	1 seagull	Leachate from refuse
8/24	3 loads	1,750	92	Calm	Overcast	Negligible	None	None	few birds	Birds have not yet located new site.
8/30	CONSULTANT	1,700	85	Westerly Low	Sunny	Slight	No		seagulls	No upper level leachate. Water below landfill was clear.
8/31	6 loads	3,500	87	Calm	Sunny	Negligible	None	None	birds	Location-West bank. Cannot get to East wall of canyon yet.
9/7	6 loads	3,500	87	Calm	Sunny	None	None	None	None	Everything quiet today. Sludge was emptied before trash was spread
9/13	Cancelled this week - dozer broke down									
9/21	6 loads	3,500	78	Calm	Cool	None	None	flies	None	Quiet
9/21	CONSULTANT 7 trucks	3,500	75	Low	Overcast	Slight	No	flies before sludge applied	None	Dumped Tuesday morning. Thousands of flies

*Enter - Calm, Low, Moderate, or High

+Enter - Sunny, Cloudy, Overcast, Showers, or Rain

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
										(green blow flies and large $\frac{1}{4}$" house fly type) were on the solid waste, with or without sludge on its surface. Flies didn't discriminate between sludge and regular waste.
9/28	Cancelled this week – dozer broke down									
10/4	6 loads	3,500	86	Calm	Sunny	None	None	flies lizards	seagulls	None
10/12	6 loads	3,500	81	Calm	Cloudy	Negligible	No	None	seagulls	
10/19	6 loads	3,500	74	Calm	Sunny	Negligible	No	None	seagulls & other birds	Thin sludges, lots of runoff 3250 gal
10/26	6 loads	3,500	63	Moderate	Sunny	None	No	None	seagulls & other birds	Regular landfill blowing litter.
11/2	6 loads	3,500	63	Moderate	Sunny	Slight sewage odor for 15 minutes	None	None	seagulls & other birds	Some litter blowing at regular landfill
11/9	6 loads	35,000	64	Calm	Sunny	No	None	None	birds	

*Enter – Calm, Low, Moderate, or High

+Enter – Sunny, Cloudy, Overcast, Showers, or Rain

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

1971 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
11/16	6 loads	35,000	70	Low	Sunny	No	None	None	Closed	Old landfill closed 11-13-71 all dumping at new location.
11/23	6 loads	35,000	68	Low	Sunny	No	None	None	Closed	Used shot gun wit bird dispursing shells.
11/30	6 loads	35,000	64	Calm	Sunny	None	None	None	Closed	
12/7	6 loads	35,000	63	Calm	Sunny	No	None	seagulls	Closed	Just a few seagulls. Do not settle down as they did at old fill site, but fly high and land when area is unoccupied by men and equipment.
12/14	6 loads	35,000	64	Low	Sunny	No	None	seagulls	Closed	
12/21	6 loads	35,000	55	Calm	Overcast	No	None	seagulls	Closed	
12/21	CONSULTANT Normal	3,500	60	Calm	Overcast	Musty, light	No	No		Sludge was unloaded at 1 spot only and flooded 2/3 down face of fill, went below refuse and exited onto canyon floor (200 gals ±)

*Enter - Calm, Low, Moderate, or High
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain

APPENDIX E
FIELD TEST OF SLUDGE DISPOSAL

Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
12/28 1972	6 loads	35,000	54	Calm	Rain	No	No	None		
1/4/	6 loads	35,000	55	Low	Sunny	Very slight	No	few birds		Sludge not being spread over trash
1/11	6 loads	35,000	62	Calm	Sunny	No	No	None		Poor coverage
1/18	6 loads	35,000	46	Calm	Overcast	No	No	seagulls		
1/25	6 loads	35,000	52	Calm	Sunny	No	No			
2/1	All sludge being dumped on top in test cells (7 to 1 ratio)									
2/15	All test cells filled with trash and sludge and covered. Sludge now being dumped with trash in bottom of canyon.									

* Enter - Calm, Low, Moderate, or High
+ Enter - Sunny, Cloudy, Overcast, Showers, or Rain

APPENDIX F

FIELD TEST OF SLUDGE DISPOSAL

APPENDIX F
FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
5/1	(truck avg 3¼ ton/ea) 33 loads	(10,500 small truck) 8,500			Hazy	Normal	No	seagulls	flies blackbird seagulls	
5/2	22 loads									
5/3	22 loads	7,500	70	Slight	Good	Normal trash smell	No	seagulls	seagulls blackbird	
5/4	22 loads	10,000	78	None	Overcast		No	seagulls	seagulls blackbird	
5/5	33 loads	21,000 (big truck)	76					seagulls pigeons		
5/8	25 loads	10,500	60	Slight	Clear	Normal	No		seagulls	
5/8	CONSULTANT		67	Low	Cloudy	None	No	30 seagulls 20 crows 25 pigeons 1 squirrel 100 birds	squirrels	Morning sludge dumped on top of fill soil from Sat. Birds avoid sludge covered areas. 1 jack rabbit, 4 squirrels not in test area.
5/9	20 loads	17,500	62	Slight	Clear	Normal	No	seagulls	squirrels seagulls	No litter when use water.
5/10	20 loads	14,000		None	Cloudy		No		seagulls blackbird	Soto on dozer for a few days.

*Enter - Calm, Low, Moderate, or High

+Enter - Sunny, Cloudy, Overcast, Showers, or Rain

Page 1 of 4

APPENDIX F
FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
5/11	22 loads	14,000	63	None		Normal	No	seagulls	seagulls	Using water on litter
5/11	CONSULTANT		75	Low to moderate	Sunny		None, using water	100 seagulls chipmunk 30 pigeons 20 misc birds		2 walking on sludge
5/12	33 loads	10,500	64		Cloudy	Normal	No	seagulls		
5/15	30 loads		63	Calm	Sunny	Normal	None	None	None	At 10:30 a.m. quiet and calm
5/16	20 loads	21,000	64	Calm	Sunny	Normal	None	None	seagulls	
5/17	22 loads	21,000	63	Moderate	Overcast	Normal trash smell	No	None	seagulls blackbird	
5/17	CONSULTANT		68	Low	Sunny	Normal	None			A couple sludge loads brought a.m No sludge visible on face of refuse. Small amount visible on plateau below face in two streamers. Took photos
5/18	20 loads	17,500	62	Calm	Sunny	Normal	No	None	squirrel seagulls	
5/19	31 loads	17,500	60	Moderate	Showers	Normal	No	birds	seagulls	

*Enter - Calm, Low, Moderate, or High
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain

Page 2 of 4

APPENDIX F
FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
5/22	33 loads	17,500	60	Low	Showers	Normal	A little	seagulls	seagulls	Some litter because of wind
5/23	20 loads	21,000	63	Calm	Overcast	Normal trash odor	No	seagulls	birds, flies seagulls	
5/24	20 loads	31,500	65	Low	Sunny	Normal	No	seagulls	seagulls	
5/25	21 loads	10,500	62	Moderate	Overcast	Sewer and trash odor	Some	None	blackbirds seagulls	Litter because of wind coming up canyon.
5/26	33 loads	21,000								
5/29	8 loads	None	65	Calm	Sunny	Normal sewer odor	None	None	seagulls squirrel blackbirds	Only 4 trucks as holiday
5/30	20 loads	24,500			Sunny		None		seagulls squirrel birds	
5/31	22 loads	7,000	68	Calm	Sunny					
6/1	30 loads		67	Moderate	Cloudy, Sunny	Sewer odor	None	birds	seagulls flies squirrels	Ending this lift and will have trouble when start the next level
6/2	30 loads		63			Trash and sewer odor	None	birds seagulls	seagulls squirrels birds	

* Enter – Calm, Low, Moderate, or High
+ Enter – Sunny, Cloudy, Overcast, Showers, or Rain

Page 3 of 4

APPENDIX F
FIELD TEST OF SLUDGE DISPOSAL

1972 Date	Solid Waste, Lb	Sewage Sludge, Gal	Weather			Odor, Describe	Blowing Litter	Birds, Rats, Other, No.		Comments
			Temp °F	Wind*	Condition+			Test Area	Regular Landfill	
6/3	40 loads	None	66	Moderate	Overcast, Hazy	Normal	None	seagulls birds	seagulls birds	Make up day for holiday -trash only
6/5	30 loads		69	Moderate	Cloudy	Normal	None		seagulls squirrels	
6/6	20 loads		63	Moderate	Overcast, Rain	Normal	None		birds seagulls	Some litter. Short of help to clean up
6/7	22 loads		62	Moderate	Showers	Sewer odor	None		squirrel birds seagulls	

*Enter - Calm, Low, Moderate, or High
+Enter - Sunny, Cloudy, Overcast, Showers, or Rain

Page 4 of 4

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer JIM REED

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Con-dition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
7/17	WD-6 Other-1	1-LS(2500)	79	Low	Sunny	Truck, gravity feed; single hose w/flat head; truck no motion; wet; slope 45% approximate. Sludge worked in after spreading by use of tractor.	0	
7/18	-	-	-	-	-	(No report) no sludge - truck broke down		
7/19	-	-	-	-	-	(No report)		
7/20 0915	WD-3 Other - 3	2-LS(3500) 2-BV(3500)	77	Low	Cloudy		0	
1330	WD-7 Other - 8	2-LS(3500)	81	Low	Sunny		5	
7/21 0930	WD-2	4-LS(3500)	75	Low	Cloudy		20	

*Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

+Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: 3-LS (3,500) (SD).

#Enter - calm, low, moderate or high. **Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer JIM REED

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Condition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample when observed)
7/21 1230	WD-6 Other-4	4-LS(3500) 6-BV(3500)	81	Low	Sunny		10	
7/24 1230	WD-4 Other-3	4-LS(3500) 2+BV(3500)	89	Mod	Sunny		20	
7/25 0850	WD-2 Other-1	4-LS(3500) 2-SLR(3500)	80	Low	Overcast		10	
7/25	--	--	--	--	--			
7/26 1100	WD-3 Other-3	4-LS(3500) 2-BV(3500)	80	Low	Sunny		20	
7/26 1300	WD-6 Other-4		81	Low	Sunny		0	
7/27 1100	WD-3 Other-2	4-LS 2-SLR	82	Low	Sunny		0	
1400	WD-7 Other-4	2-SLR	84	Low	Sunny		5	

[*] Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads".

[+] Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: 3-LS (3,500) (SD).

[#] Enter - calm, low, moderate or high. [**] Enter - sunny, cloudy, overcast, showers or rain.

DS-1: SLUDGE APPLICATION DATA - FIELD TEST OF SLUDGE DISPOSAL Observer JIM REED

Date & time	Loads disposed, no.		Weather			Sludge disposal	Est. qty, gallons	
	Solid waste by type*	Sludge load by type+	Temp. °F	Wind#	Con-dition**	Describe method of sludge and solid waste placement, and condition of sludge when observed (wet, dry)	Runoff	Leachate (sample whe observed)
7/28	WD-1	4-LS(3500)	85	Low	Sunny			
0900	Other - 3	2-BV(3500)						
1400	WD-4		87	Low	Sunny			
7/31	WD-3							
1000	Other - 2							

---

[*] Type of load: for WD (Waste disposal collection trucks) enter "WD-no. loads". For other loads indicate "Type-no. loads"

[+] Indicate type of sludge as: SLR-no.(gallons/load); and for Buena Vista (BV) and La Salina (LS) note primary digested (PD), primary raw (PR) or secondary digested (SD) sludge. Example: 3-LS (3,500) (SD).

[#] Enter - calm, low, moderate or high. [**] Enter - sunny, cloudy, overcast, showers or rain.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reed

Date & time	Sludge test area: 150 ft x 200 ft						(No sludge) Regular landfill area: 200 ft x 200 ft					
	Blowing litter, no.items[*]	PA = 30,000 ft.^{2} Animals and insects, no/PA[+]				Odor[‡]	Blowing litter no. items[*]	Animals and insects, no/PA[+]				Odor[‡]
		Birds	Rats	Flies	Others[!]			Birds	Rats	Flies	Others[!]	
7/17 1100	0	0	0	100	None	Earthy	0	0/ 40,000 ft.^{2}	0/ 4(10^4) ft.^{2}	100/9 ft.^{2}		
7/18	No sludge	disposed										
7/19												
7/20	0	0	0	100	None	None						
7/20	0	0	0	100	None	None						
7/21 0930	0	2	0		None	None						
7/21 1230	0	2	0	100	None	None						
7/24	0	0	0	0	None	None						

[*] Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

[+] Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

[#] Estimate the area covered by flies and the number of flies, maggots.

[‡] Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

[!] Indicate rats, cats, dogs or other unusual animal or insect or event.

DS-2: ENVIRONMENTAL OBSERVATIONS - FIELD TEST OF SLUDGE DISPOSAL Observer Jim Reed

Date & time	Sludge test area: 200 ft x 200 ft						(No sludge) Regular landfill area: ft x ft					
	Blowing litter, no. items*	PA = 40,000 ft.^{2} Animals and insects, no/PA+				Odor‡	Blowing litter no. items*	Animals and insects, no/PA+				Odor‡
		Birds	Rats	Flies	Others!			Birds	Rats	Flies	Others!	
7/25 0850	0	0	0	50/9	0	None						
7/25												
--	--	--	--	--	--	--						
7/26	0	0	0	0		None						
7/27 1100	0	0	0	50/9		None						
1400	0	0	0	0		None						
7/28 0900	0	2	0	20/5		None						
1400												
7/31 1000	0	0	2	100/9		Earthy						

---

[*] Estimate the number of items travelling in the wind. Do not include items waving or flapping in the wind which are held down at one end.

[+] Count the number of birds and animals on the waste fill and estimate the total area in square feet (feet). The sludge test area size shall include all solid waste fill surface which is covered with sludge or was mixed with sludge at the time of observation. PA = populated area where 80 percent or more of the observed population is foraging.

[#] Estimate the area covered by flies and the number of flies, maggots.

‡ Earthy, pig pen, sweet, etc.; none, medium, strong, etc.

! Indicate rats, cats, dogs or other unusual animal or insect or event.

APPENDIX G

OCEANSIDE LANDFILL SITE GEOLOGY AND GROUNDWATER CONDITIONS

APPENDIX G

Oceanside Demonstration Landfill Site Geology

The canyon designated for landfill is underlain by resistant, impermeable bedrock with a layer of fine alluvial deposits of relatively low permeability and undetermined thickness lining the canyon floor. Underground seepage may occur in the bedrock along bedding planes which slope to the southwest (see sketch on Figure G1), or through the fine alluvium. Marine terrace deposits along the top of the canyon walls are permeable.

Landfill cover soils are coarse to fine sand cut primarily from loose areas of the landfill canyon walls. Additional cover soils are imported. Sieve analysis of cover soil samples from the three test cells and the landfill given in Figures G2 and G3 indicate that the soils are coarse to fine sand.

No landslide, mud flow, other mass movements or soil creep were evident at the landfill site. The canyon walls consist of well-consolidated sandstone in the upper-canyon areas, some of which has been difficult to remove for use as landfill cover soil.

Groundwater

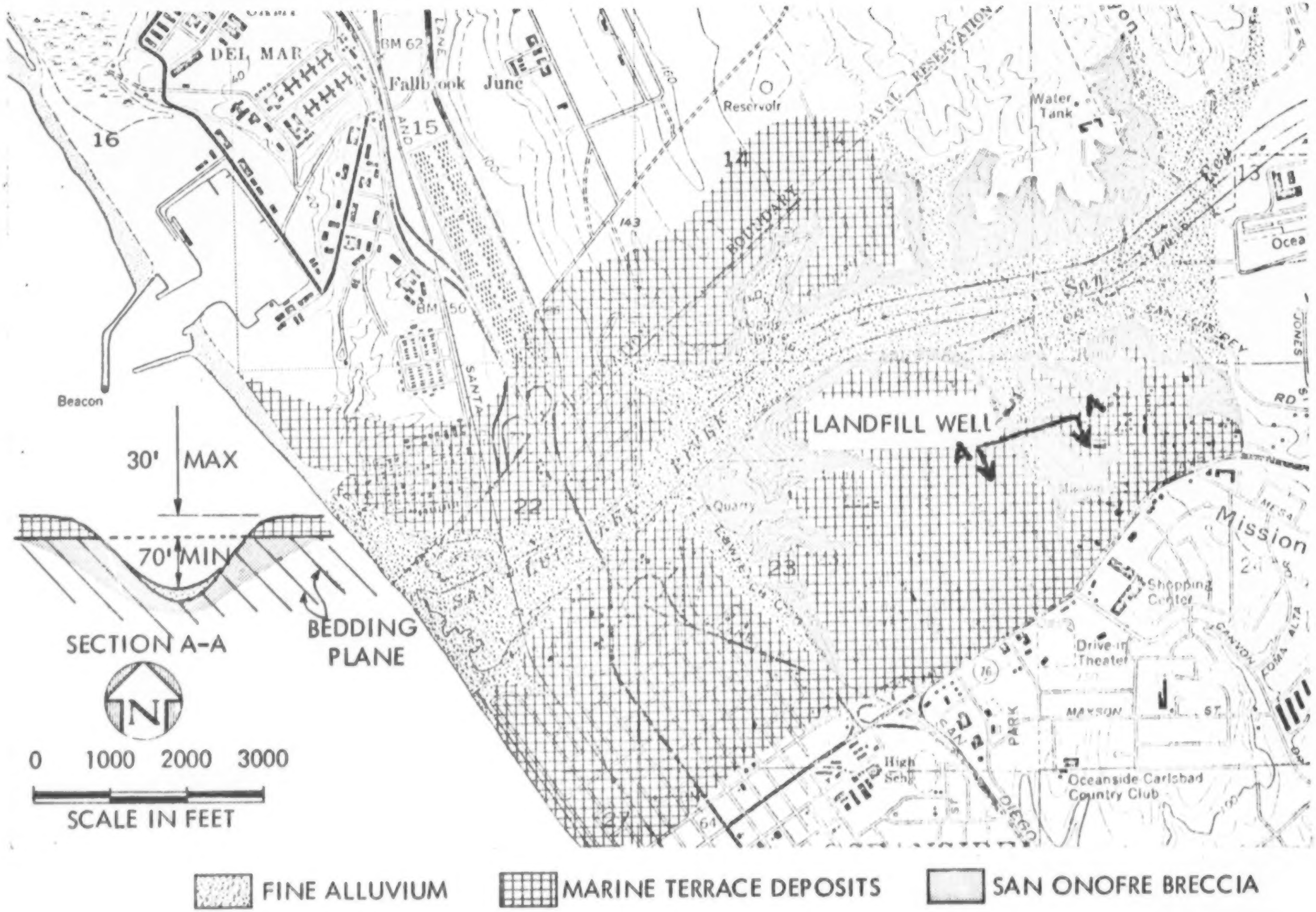
No natural groundwater spring or seepage was observed in the landfill canyon. A test well installed approximately two-thirds of the distance from the upper canyon wall to the downstream San Luis Rey River basin (see Figure G1) indicated a groundwater level of 14 to 17 feet below the surface. Analyses of well water samples are given in Table G1. The well water quality is not suitable for human or animal consumption due to the presence of coliform. Also, the dissolved solids and sulfate concentrations exceed drinking water standards. The coliform presence may be due to well contamination rather than being from seepage of bacteria into the groundwater aquifer by percolation. No other wells exist in the canyon and therefore no groundwater problems are expected.

TABLE G1

OCEANSIDE LANDFILL WELL WATER ANALYSES IN MG/L EXCEPT AS NOTED

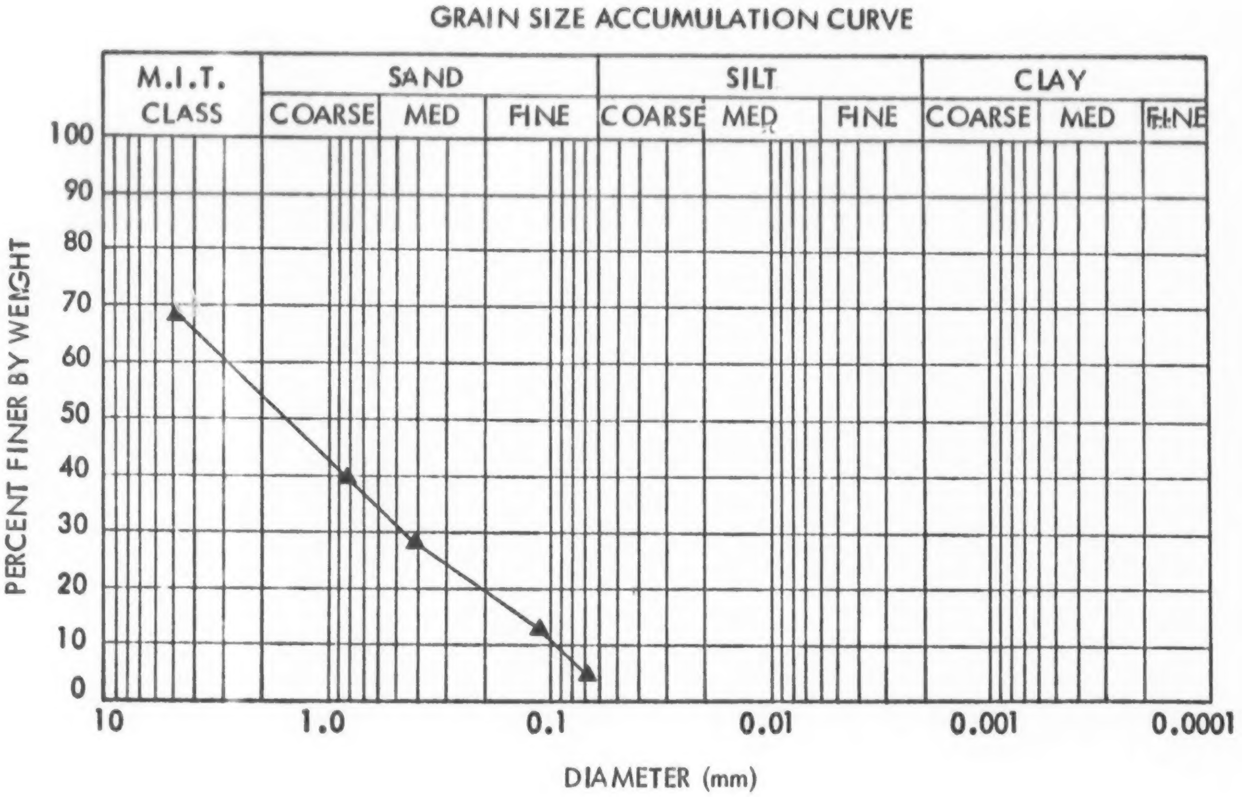
Constituents *	Sample date 3/1/72
pH	7.6
Coliform	43
Total solids	740
Suspended solids	14
Dissolved solids	726
Volatile suspended solids	14
Calcium	104
Sodium	102
Ammonia (NH_4)	0.61
Carbonate (CO_3)	0
Bicarbonate (HCO_3)	37
Sulfate (SO_4)	429
Chloride	80
Flouride	0.04
Total phosphate	1.9
Nitrite	0.008
Nitrate	0.01
Ammonia (N)	0.47
Total alkalinity ($CaCO_3$)	412
Total hardness ($CaCO_3$)	298

*All analyses are in units of mg/l except pH and coliform (MPN/100 ml).


DEL MAR
16
BM 62
Fallbrook June
15
Reservoir
14
NAVAL RESERVATION
BOUNDARY
143
160
Water Tank
13
San Luis Rey
SAN LUIS REY
Ocea
JONES
RD
Beacon
BM 56
SANTA
LANDFILL WELL
A
A
22
Quarry
23
Mission
24
Shopping Center
Drive-in Theater
PARK
MAXSON
ST
LOMA ALTA
CANYON
16
SAN DIEGO
High Schl
Oceanside Carlsbad Country Club
21
64
30' MAX
70' MIN
BEDDING PLANE
SECTION A–A
N
0 1000 2000 3000
SCALE IN FEET
FINE ALLUVIUM
MARINE TERRACE DEPOSITS
SAN ONOFRE BRECCIA

CITY OF OCEANSIDE/E.P.A.

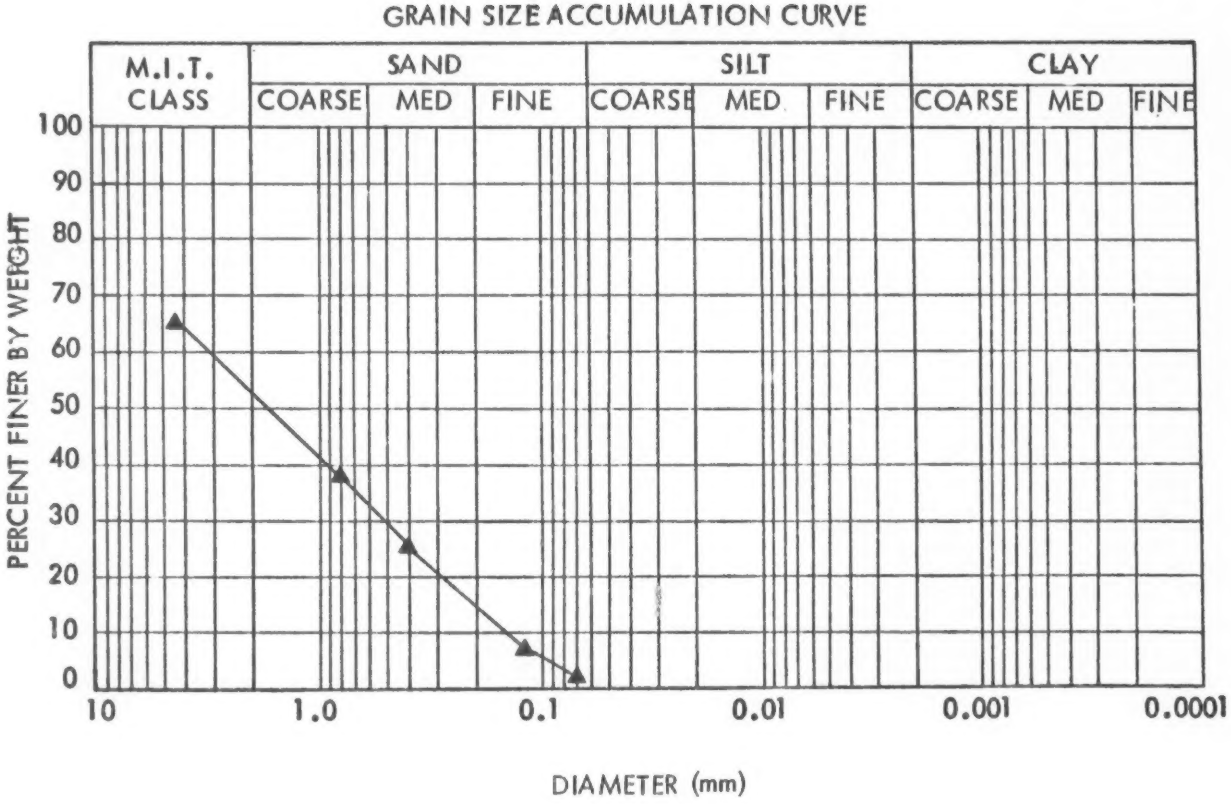
FIGURE G1
GEOLOGIC MAP
OF LANDFILL SITE



CITY OF OCEANSIDE/E.P.A.

FIGURE G2

FIELD TEST CELL
COVER SOIL COMPOSITE
SAMPLE



GRAIN SIZE ACCUMULATION CURVE

CITY OF OCEANSIDE/E.P.A.

FIGURE G3

LANDFILL COVER SOIL
COMPOSITE SAMPLE